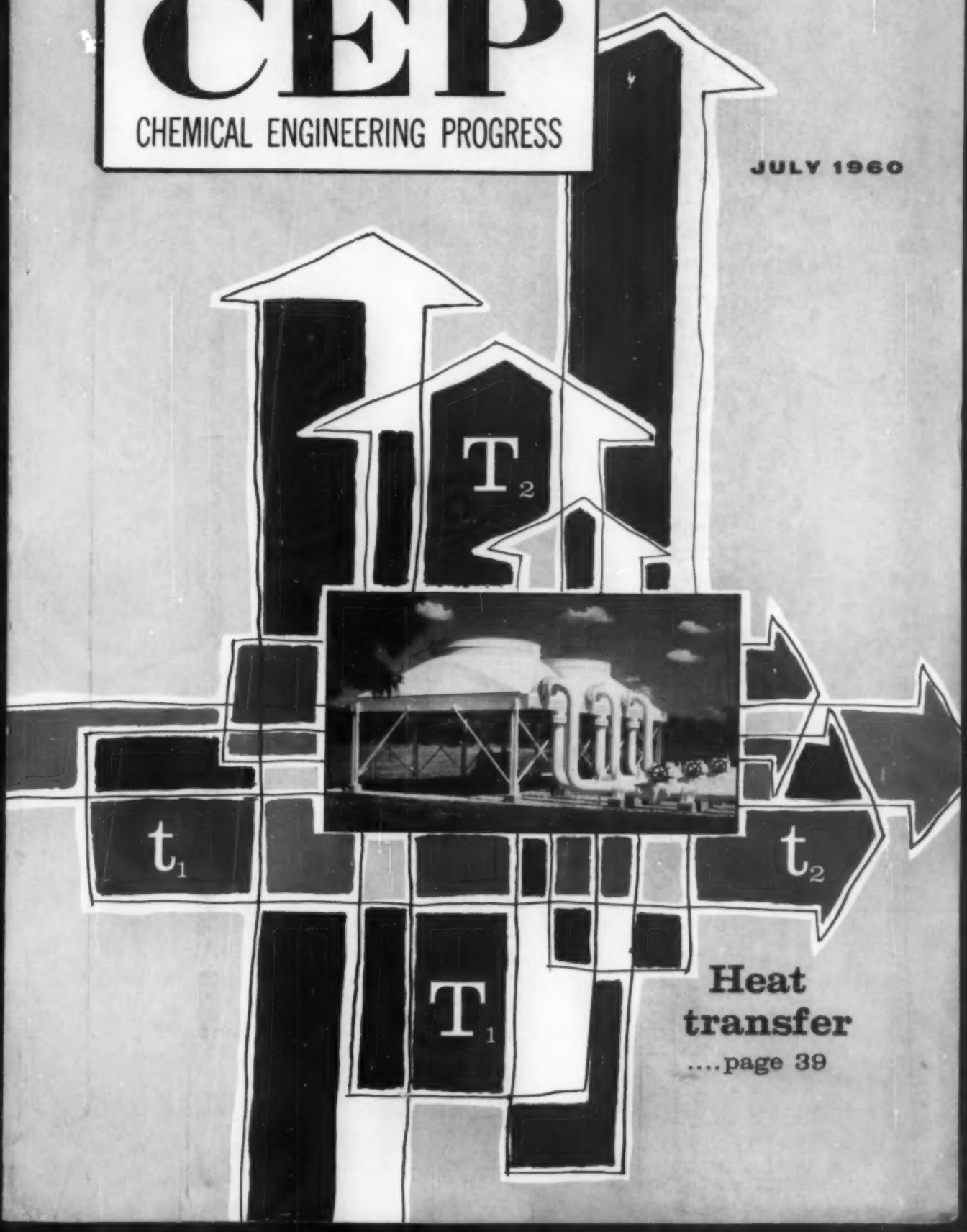
CEP

CHEMICAL ENGINEERING PROGRESS

JULY 1960



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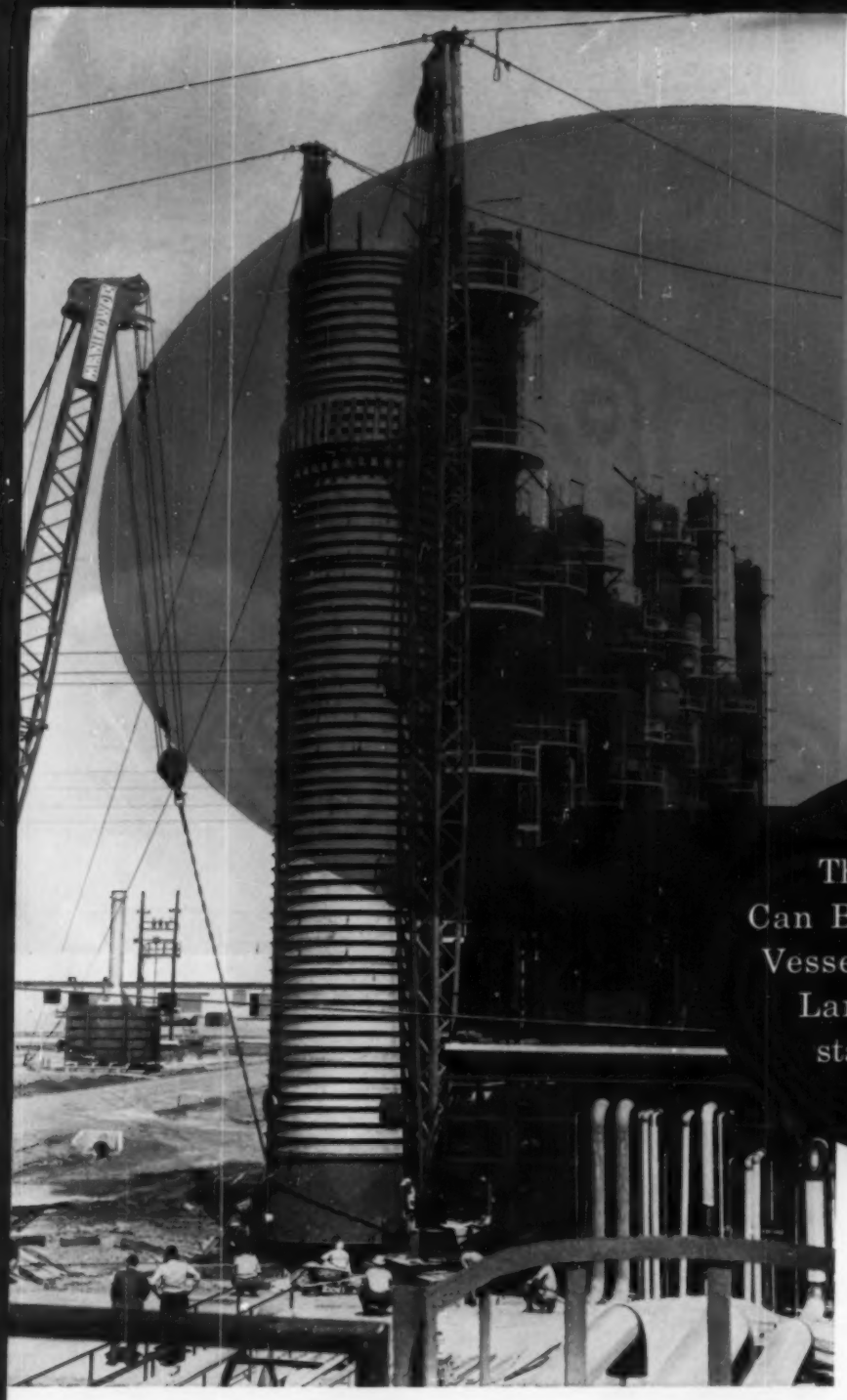

Here the vacuum tower of stainless steel construction is being erected, the last of four vessels that went into recent expansion of the petrochemical facilities of the Celanese Chemical Company at Pampa, Texas.

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Cover by Paul Arlt. Photo of air-cooled heat exchanger courtesy Hudson Engineering Co.

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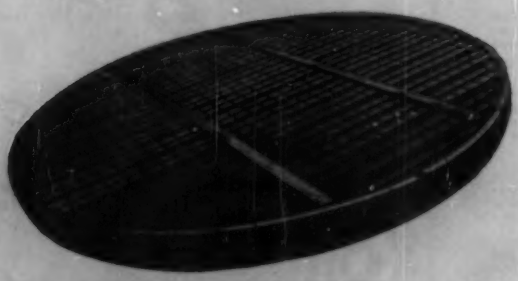

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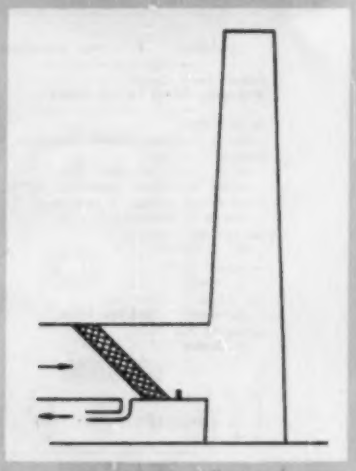
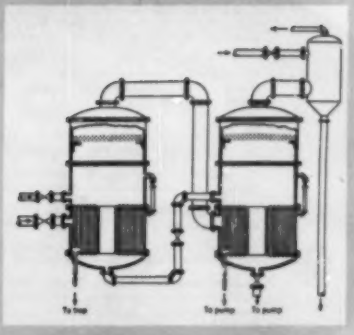
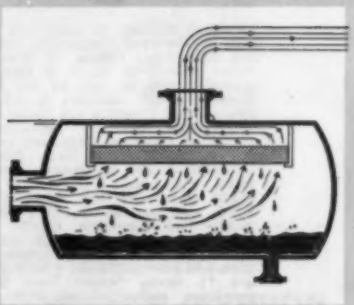


Demisters prevent air pollution by removing liquid contaminants. If stack velocity is too high, the demister may be installed in a duct or separator vessel.



YORKMESH DEMISTERS installed in evaporators avoid product loss and provide clean condensate.



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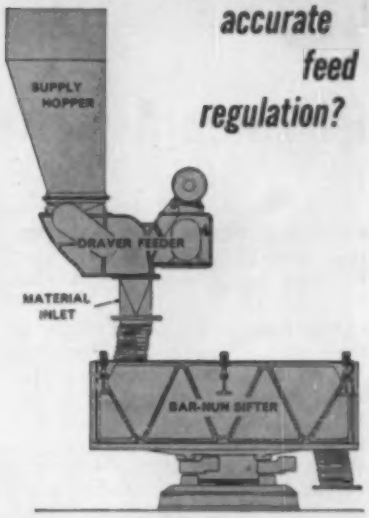

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book reviews

Petroleum in America

AMERICAN PETROLEUM REFINING, H. S. Bell, D. Van Nostrand Co., Inc., Princeton, N. J. (1959), 538 p., $12.50.

This book is the fourth edition of the very well known work by H. S. Bell on the American petroleum refining industry. In the preface to this latest edition the author states that it is the purpose of his book "to provide a concise summary of the techniques of petroleum refining in its many and varied phases. . . . Papers and articles in the technical press have become numerous, and, in fact, entire volumes have been written on subjects covered by a section of this book. The purpose of this volume is to combine this information, and to make it readily available to students and to the executive, engineer, or employee of the industry seeking up-to-date facts."

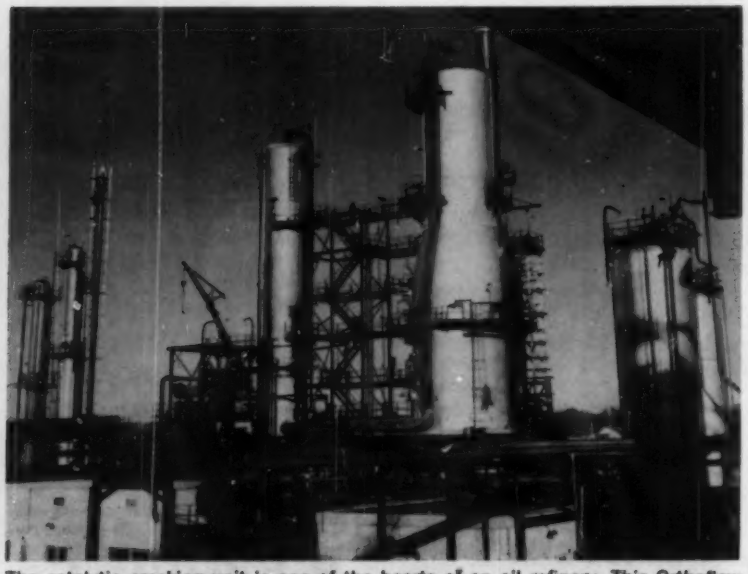
This book does indeed present, in a concise but very sketchy manner, the various aspects and processes of the petroleum industry. When one considers that the book contains only 538 pages, it is obvious that only a very brief discussion can be devoted to any one of the very many processes and engineering considerations that go into the arrangement and design of a modern refinery.

Those sections of the book devoted to the engineering principles, and physical and thermodynamic properties of materials encountered in refinery engineering, are so sketchy and simplified that they are of practically no value to the engineer who is actively engaged in the operation or design of petroleum equipment. The material and discussions would be of most use to technicians and operators whose formal education in physical chemistry is very incomplete. For those people the descriptions and discussions, combined with the literature references cited, would be sufficient as a preliminary to a more comprehensive study of the subject matter. As an example, there is no discussion of the quantitative deviations from perfect-gas laws or ideal solutions, nor is any information given on the deviations of mixtures of materials from the properties of single components.

The information presented with flow sheets on the various processes used in the petroleum industry is an excellent survey and summary concisely presented. Operating conditions, throughputs, and yields covered here should be very useful to the executive who desires only approximate figures for qualitative comparisons. The discussion in the back of the book on the factors pertaining to the storage of oil, evaporation losses and fire protection, is valuable and a handy reference for those not normally engaged in this facet of the industry.

Uninformed readers may also be somewhat confused by typographical errors which appear in various places. The reviewer, without too close a scrutiny, found several instances where authors' names and compounds are misspelled.

Reviewed by Leo Friend, Associate Director of Chemical Engineering, The, M. W. Kellogg Co., New York 17, N.Y.



The catalytic cracking unit is one of the hearts of an oil refinery. This Orthoflow cracker is at the Ponca City, Oklahoma, refinery of Cities Service.

THE ENGINEERING INDEX—1959, Edited by Carolyn M. Flanagan et al., Seventy-fifth Edition, The Engineering Index, Inc., 29 West 39th Street, New York, 18. 1600 pp., $70 postpaid.

Publications of engineering, scientific and technical societies; engineering and industrial periodicals; and reports of government bureaus, engineering experiment stations, universities, and other research organizations are reviewed. Not necessarily all articles contained in these publications are indexed. Selection is made on the basis of articles dealing with the art and science of engineering. Articles on pure science, economics, commerce and trade, editorials, news items, notices of meetings, trade announcements, and the like, are included only if these are considered of prime importance. *The Engineering Index* contains a 12 page list of technical publications received by The Engineering Societies Library and reviewed by *The Engineering Index*. 96 pages are devoted to an authors index. Of the 1700 technical publications reviewed, 679 come from 44 foreign countries and the balance from the U.S. Following is a list of the foreign countries from which the publications come: England, 218; Germany 89; France 58; Canada 34; Japan 26; USSR 41; Australia 23; Belgium 23; Sweden 23; Italy 18; Switzerland 18; India 17; The Netherlands 14; Austria 12; Argentine 11; Poland 11; South Africa 11; Den-

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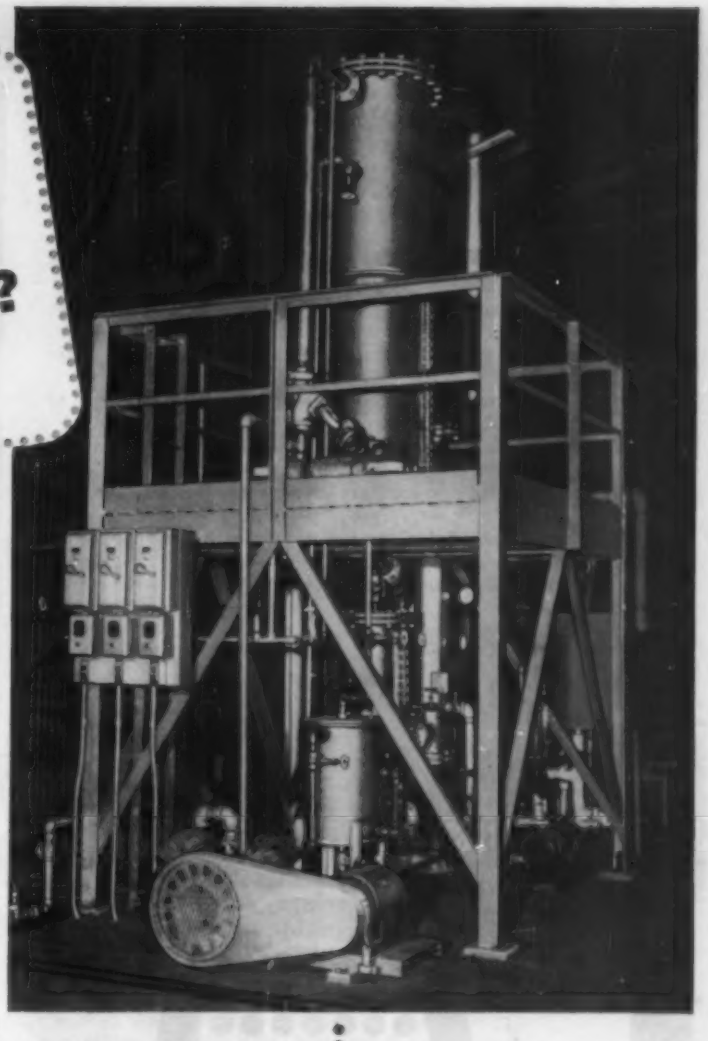

CB&I pilot plant facilities are available for determining heat transfer coefficients on unknown materials. Typical evaporator-crystallizer unit at right provides valuable data for design of processing equipment.

In the design of heat transfer units, such as multiple effect evaporators and crystallizers, there is no substitute for experience and equipment. This is why so many *companies with heat transfer problems* bring them to CB&I.

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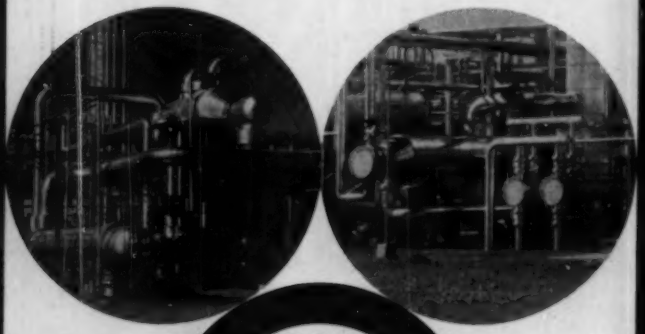

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PROCESS EQUIPMENT DESIGN, L. E. Brownell and E. H. Young, John Wiley and Sons, Inc., New York, N. Y. (1959), 408 p., $19.50.

This book is a notable contribution to engineering literature, putting under one cover the most comprehensive theoretical and practical treatment of vessel design yet available. It is useful:

1. To the student as a text giving the theoretical basis for vessel design as well as a sound coverage of industrial practices.

2. To the vessel designer as an excellent reference for empirical and approximate methods for stress conditions which cannot be covered by code. Alternate methods are given where merited.

3. To the engineer concerned with selecting the most economical vessel design.

The first 12 of the 15 chapters develop in a logical sequence fundamental relationships on which many code specifications are based. Chapter 13 deals entirely with code practices. Chapters 14 and 15 deal with considerations of design beyond the ASME Code (high pressure monobloc and multilayer vessels).

Reviewed by B. B. Kuist, manager of projects, The Fluor Corp., Ltd., Los Angeles, Calif.

AN INTRODUCTION TO RADIATION COUNTERS AND DETECTORS, C. C. H. Washtell, Philosophical Library, London (1960), 115 p., $7.50.

It is well to emphasize the word "Introduction" in the title of this book. The author indicates that this book will be followed by a comprehensive presentation in a volume entitled *Nucleonic Instrumentation*. The book contains 108 pages, the first thirteen of which are concerned with the history and discovery of radioactivity together with a simplified picture of atomic structure. Twenty-four

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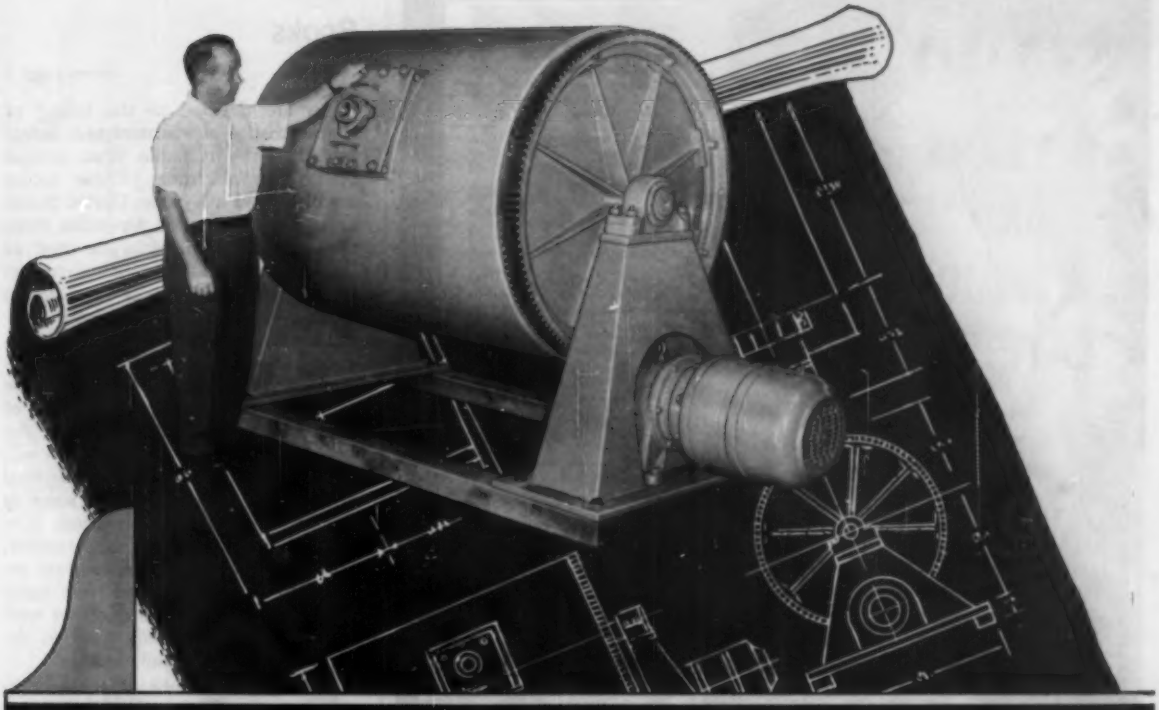

PROPER PROTECTIVE COATING IS PART OF THE DESIGN

The modern product designer recognizes that his responsibility doesn't end until the product's *finish* has been specified. This is especially important when new machinery or equipment is destined for operation in areas where exposure to acids, corrosive fumes or high humidity may be a factor.

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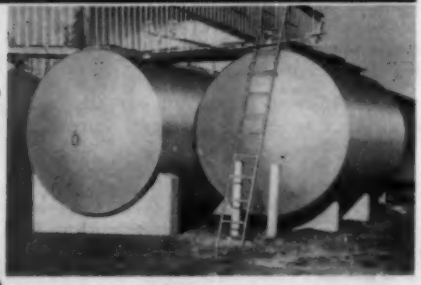

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Books

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pages are devoted to the listing of characteristics of counters and detectors that are available from several British manufacturers. These tables are of limited use in the United States since no products of American firms are listed. The material devoted to discussion of counters and detectors is treated only in a qualitative manner.

Persons who have had no experience with counters or counting equipment, or persons who have had some experience with a particular type of counting equipment, will find the book easy to read. The reader will learn something about the physical appearance of the detectors, some of the techniques of construction, how detectors compare with one another, etc. Probably the most important result that can be obtained from study of the book is a familiarization with nomenclature commonly used in describing detectors and counters.

There is no doubt that new uses for these instruments will continue to be found in chemical fields, including production and research. The *possible* uses in the chemical fields are virtually limitless. Unfortunately, this book will seldom answer questions for a chemical engineer who is faced with a problem that may have a solution in radioactive techniques. It *may* give him the vocabulary necessary to communicate with others concerning his problem. The book contains no references to assist the ambitious reader to expand his knowledge.

In summary, this book may be easily read by the novice who seeks information under the classification "general knowledge", but it is not useful as a reference book, nor does it measurably aid in the solution of specific problems.

Reviewed by Richard C. Bailie, Dept. of Nuclear Engineering, Kansas State University, Manhattan, Kansas.

ENGINEERING STATISTICS, Albert H. Bowker and Gerald J. Lieberman, Prentice-Hall, Inc., New York, N. Y. (1959), 585 pp., $11.00.

Statistics and statistical methods are becoming more and more important in the work of many chemical engineers. Universities have been recognizing this need by providing additional courses in the field. *Engineering Statistics,* as the author's pref-

continued on page 12

IN I-R COMPRESSORS,
TIME TELLS
THE DIFFERENCE

This I-R non-lubricated compressor has operated

34,640 HOURS

with original wear ring—and still going strong!

In July, 1950, a prominent manufacturing company purchased an Ingersoll-Rand ES-NL non-lubricated compressor to supply oil-free air for its Cincinnati plant. At this writing, the unit has operated for 34,640 hours, at an average of 70 hours per week, with the original piston and wearing ring – and it's still going strong.

The piston compression rings were changed once, during routine inspection in 1955.

It takes a special breed of compressor to withstand thousands of hours of continuous service without lubrication of any kind. It's one of the toughest jobs a machine is asked to do, and dependability is the first requirement. Of course, many different factors determine the life of non-lubricated equipment – condition of gas handled, pressures, operating practices, type of service – but you'll find that Ingersoll-Rand NL compressors have the best reputation for dependability in all kinds of jobs.

Ingersoll-Rand introduced the non-lubricated compressor principle in 1933, and today builds the widest range of types and sizes. The Ingersoll-Rand air-cushioned NL Channel Valve is the only valve designed specifically for non-lubricated operation. Ingersoll-Rand NL compressors have a number of other exclusive *Extra-Value* features, and each unit is engineered for its specific job.

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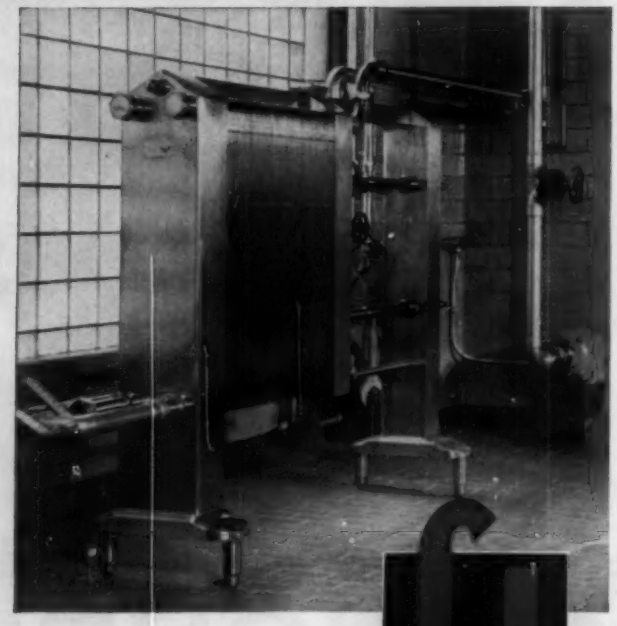

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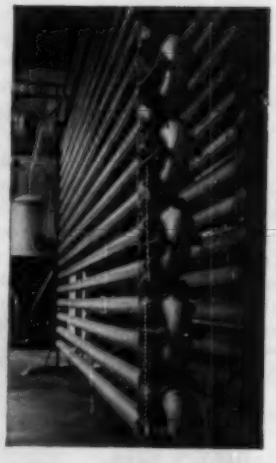
Chester-Jensen Plate Heat Exchangers
Heat
Cool
Regenerate

AT the famous brewery of D. G. Yuengling & Son, "Brewers Since 1829," in Pottsville, Pa., it was desired to reduce the cost of cooling wort to the absolute minimum . . . and so the double-pipe wort cooler shown at right below was replaced with the Chester-Jensen Plate Heat Exchanger shown above. Result:

50% **Reduction in cooling time,** using chilled water only instead of water and brine.

50% **Reduction in refrigeration load** (37°-38° chilled water to cool 180°-190° wort to 50° at 208 bbls./hr.)

92% **Reduction in floor space** occupied by cooler. (Installation released some 600 sq. ft.)



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Books

from page 10

ace states, is intended as a text for a first course in statistics for students in engineering and the physical sciences. This book would be a good text for the student desiring a reasonable mathematical foundation without going into theoretical detail. A good text for course work, however, is not necessarily a good book for the chemical engineer, who, long out of college, does not have tutorial services available. In this case the language, logic, and clarity of the text become more important. It is from this viewpoint that this review is written.

In general the descriptive text is clear and concise. Many practical examples, framed in engineering contexts, are presented. The text covers the major subjects usually found in introductory texts and includes the development of distributions and the notion of probability statements; hypothesis testing and estimation; analysis of variance; and sampling procedures. This book is a worthy addition to the library of a reader who plans to pursue seriously a self-education plan, or who can use the many computing formulas and curves presented.

The development of probability distributions is done in a logical fashion with early introduction of measures of central tendency and variance. To comprehend fully the details of the several probability distributions discussed, the reader may well have to review his long neglected text from elementary calculus. However, this book has divided sections with "detailed or difficult mathematical arguments". The omission of these sections does not destroy the continuity. However, if these sections are omitted, certain statements must be accepted on faith.

One of the most outstanding features of this book is the early introduction and extensive use of Operating Characteristic (OC) Curves. These curves graphically convey the concept of the two types of statistical errors. (Type I and II errors, γ and β risks). Development of optimum decision rules is based on this framework.

Quality control and sampling procedures are included with a complete section of sampling tables. Sequential sampling is briefly described.

Reviewed by R. V. Kahle, Operations Research Section, Esso Research and Engineering Company.

LGP-30 COMPUTER ABSTRACTS

(Application Report #10, from which the following is abstracted, is free upon request from Royal McBee Corporation, Data Processing Division, Port Chester, N. Y.)

Subject: Design / User: Brown Fintube Company, Elyria, Ohio

The Problem: rush quotation for heat exchanger to potential customer. Determine best heat exchanger vs. cost combination. Perform necessary computations to obtain values for total surface area; total number of exchangers; area/exchanger; velocity and pressure drop—shell and tube; film coefficient; log mean temperature difference; overall transfer rate; clean rate; overall fouled rate; surface actually required; duty; price.

Method: the compact, low-cost Royal Precision LGP-30 Electronic Computer.

Input Data: except for special specifications which are handled by design engineers, non-technical personnel fill in data directly from customer inquiry sheets. This information is then punched on tape.

Solution: the engineer reads the above data into storage in specifically assigned memory locations on the computer's magnetic drum. The set of program instructions—also stored on the drum—then directs the computer where to find the input data and what mathematical operations to perform in the proper sequential order. The program then further directs the computer to store the various answers in specifically assigned memory locations.

Of notable interest is the incorporated test feature which allows any type and arrangement of sections to be tested by the computer. The program not only compares calculated values, but provides a corrective computation and recomputes all conditions until satisfactory values are obtained. The engineer need only type in the exact arrangement desired to have the computer calculate his proposed arrangement – assuring complete versatility and control over the program.

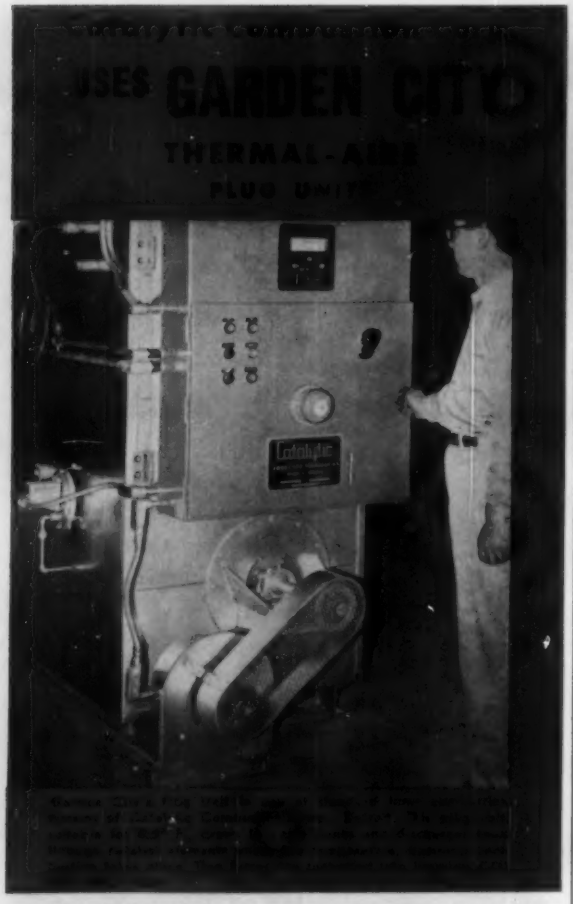
Output: all numbers required for the final specification sheet, including price, are provided – as well as key intermediate answers to enable the engineer to exercise judgment. The computer automatically controls the typewriter so that all answers are printed out in the desired format.

Conclusions: with the LGP-30, Brown Fintube has reduced total time on typical heat exchanger designs from one or two hours to approximately 3 minutes. Better design vs. cost combinations have been obtained—with a resulting increase in contract awards and the elimination of under-bidding. According to company officials, "perhaps the most significant contribution of the LGP-30 has been the release of engineering manpower for more basic and profound studies."

Royal Precision Corporation

Royal Precision is jointly owned by the Royal McBee and General Precision Equipment Corporations. LGP-30 sales and service are available coast-to-coast, in Canada and abroad through Royal McBee Data Processing offices. For your free copy of Application Report #10, as well as full specifications on the compact, mobile LGP-30, write today to **ROYAL McBEE CORPORATION,** data processing division, Port Chester, N.Y.

For more information, turn to Data Service card, circle No. 90



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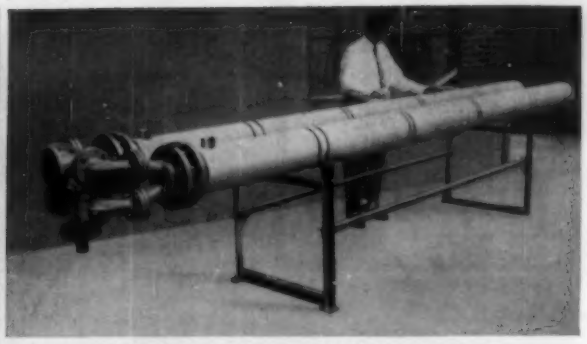

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Petrochemicals taking bigger market bite

Forty percent of U. S. chemicals sales in 1965 will be in the petrochemicals area, says Standard of N. J. executive.

By 1965, PETROCHEMICALS will make up forty percent by volume of all U. S. chemical production, predicted D. A. Shepard, Exec. V.P. of Standard Oil of New Jersey. Shepard spoke recently in Paris before the Societe de Chimie Industrielle. Present figure is around thirty percent. Total chemical industry volume, now at 80 million metric tons, will soar to 100 million by 1965, said Shepard.

The increasing role being played by petrochemicals in the overall U. S. chemical picture is evidenced by the fact that several important chemical companies now have 50 percent or more of their efforts concentrated in this area, pointed out Shepard. Leaders in this direction are:

	PETROCHEMICAL SALES AS % OF TOTAL SALES
Monsanto*	65
Rohm & Haas	60
Dow	60
Du Pont	50
Carbide	50
Cyanamid*	40
Allied	36
Hercules	15

Estimated chemical plant construction for the period 1959-1961 also brings out strongly the trend to petrochemicals:

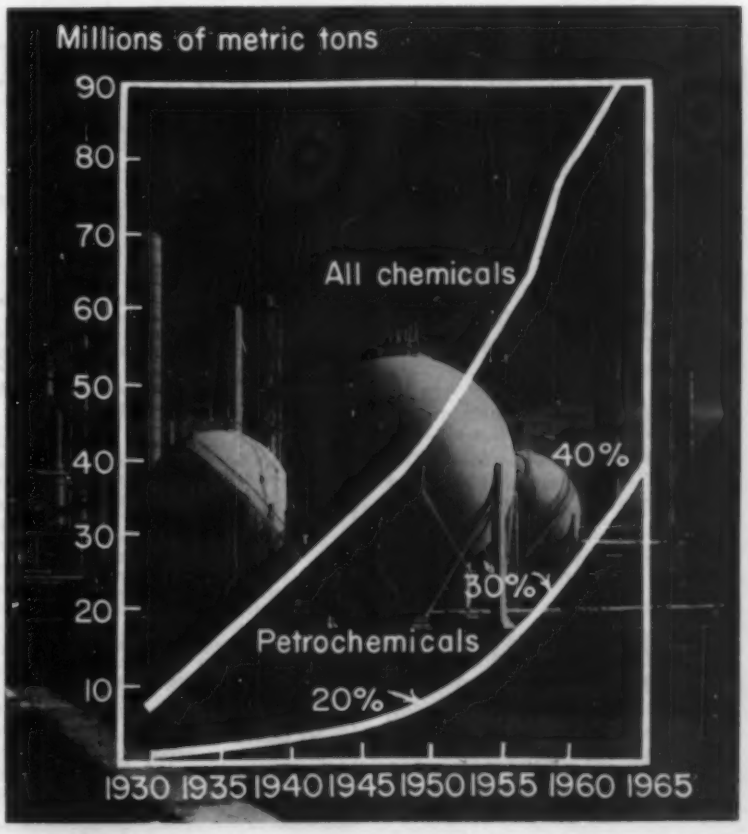
	$MM	$MM
BASICALLY PETROCHEMICAL (61.4%)		
General organic chemicals	675	
Plastics and resins	450	
Synthetic fibers	101	
Raw materials from petroleum	455	
Fertilizers	116	
Synthetic rubber	45	1,842
RELATE TO PETROCHEMICALS (12.9%)		
Laboratories	220	
Miscellaneous smaller fields	167	387
GENERALLY NON-PETROCHEMICAL (25.7%)		
General inorganic chemicals	686	
Special metals	86	772
		3,001

Excludes drugs.

American chemical interests in Europe

Participation by American chemical companies in the European chemical industry is also on the upswing, according to Shepard. He cited, among others:

Standard Oil (N.J.)—U.K., France, Germany, Belgium, Holland, Spain
Du Pont—Ireland (U.K.), Holland
Carbide—U.K., Belgium, Italy
Monsanto—U.K., Italy, Spain, Ireland (U.K.)
S.O. of Calif. (Oronite)—U.K., France
S.O. of Ind. (Amoco)—Belgium
Texas Butadiene—France, Sweden
Dow—Holland, Spain, Italy, U.K.
Goodrich Chemical—Holland
Olin Mathieson—Belgium



SCOPE

continued

Breakthrough in machine translation?

Newly-disclosed IBM system may open the door to mass translation, evaluation of complete Russian technical literature.

AN AUTOMATIC ELECTRONIC translator, developed by IBM and recently unveiled for public inspection, may have far-reaching implications for evaluation, and perhaps ultimately for translation, of foreign technical literature.

The machine presently specializes in Russian, translates Pravda daily into rough but understandable English. Speed of the system, now about 30 words per second, is limited by the speed of the punched paper tape input and the "slow" electric typewriter output. However, automatic input and output devices are under development, as well as a new solid-state, transistorized version of the translator itself, the Mark II, which will be faster, more reliable, and more compact than the present Mark I.

In addition, an automatic print reader is now in the works at Baird-Atomic, Cambridge, Mass., is expected to be operational by September of this year. Goal of the whole program is a speed of 100 words per second.

Rotating disc memory

Heart of the system is a rotating glass disc, the "photoscopic disc memory." A Russian dictionary of some 55,000 work stems, plus word endings, is arranged on about 700 almost microscopic concentric tracks in a band toward the edge of the disc. As the disc rotates at about 1,400 revolutions per minute, a beam of light matches the Russian text word to the Russian dictionary. The corresponding English words are then printed out automatically by an electric typewriter.

If the translator finds a word not in its vocabulary, it prints this word in red for later addition to the disc memory.

Fractured English

Grammar of the electronic translator, admits IBM, is "still well below college level," but a sophisticated lexical buffer and word analyzer now under development is expected to improve this in the near future. Sentences will then actually be analyzed grammatically and much smoother English produced.

Only the first step

Automatic translation of the whole Russian technical literature (a consummation devoutly to be wished, but still in the indefinite future) would, however, not be the whole answer to the present needs of our scientific and industrial community. The output is so vast and so variable in quality and usefulness that a tremendous task would still remain—evaluation, selection, editing, and publishing of what is vital.

Раскроются новые тайны Вселенной

◇

Академик В. АМБАРЦУМЯН

◇

Шестое десятилетие XX века представляет собой одну из наиболее волнующих страниц истории человечества. Социалистические страны Европы и Азии, население которых составляет более миллиарда человек, успешно продвигаются по пути строительства социализма и коммунизма. Со все возрастающей быстротой идет процесс освобождения народов многих стран, на протяжении веков колониями империалистических го В международных отношениях ус методы «холодной войны» замени ными переговорами.

Во все возрастающем темпе ра научный и технический прогресс ский Союз своими искусственными ками Земли и космическими раке ложил путь в мировое пространс

Мы, работники науки, с удовле ем смотрим на итоги оканчивающ пятилетия и убеждены, что ближа ды принесут с собой еще более по ные успехи.

В наше время наука ведет нас по всему фронту борьбы за позна природы. На некоторых участках (ние проходит особенно стремитель

Один из таких участков предста бой физика космоса. Речь идет з об исследовании планет солнечной и межпланетной среды с помощью межпланетных научных станций.

радиоспектра привело за последнее десятилетие к созданию новой науки — радиоастрономии с ее поистине феноменальными достижениями. Она позволяет исследователям проникать в область наиболее бурных нестационарных физических процессов, совершающихся в небесных телах. Если астрофизикам прошлого, вооруженным лишь

Will Open New Secret Universe

Academician V. Ambartsumyan

Sixth decade XX century represents one of the most stirring pages history humanity. Socialist country Europe and Asia, population that constitute more billion man, successfully move along the way of building socialism and communism. With all increasing speed goes process releasing peoples many country, during the period of centuries former colonies imperialistic state. In international ratios obsolete method "cold-war" replace peaceful negotiations.

In all increasing rate is developing scientific and technical progress. Soviet Union own artificial satellites Earth and cosmic rockets laid way in world space.

Industry bolsters higher education

Increasing corporate contributions to education are now being guided by a new management group that knows how, why, and where such support will do the most good.

In the last ten years, the role of leading business firms as "corporate citizens" in American life has grown tremendously. Estimates of total corporate giving to higher education are over $136 million during 1958. This is quite a difference from the figure of $24 million in 1948. Corporation contributions continue to pass swiftly from the stage of spontaneous giving under immediate pressures, to planned investment which has some relation to both the company and public interest. Such contributions are being guided more and more by a new management group that knows how, why and where this support will do the most good. This is the emerging pattern of corporate giving, says John A. Pollard, vice president—research, Council for Financial Aid to Education. His views appeared in an article in the *Harvard Business Review*.

Various companies use different methods of establishing contribution policies and of distributing grants. Some set up special committees or establish company foundations. A few appoint a special officer of the corporation to supervise the aid to education program. In some companies, the staff work on the aid to education program is under the ultimate direction of the vice president for public relations. Others manage such programs from the personnel division. In all cases the link to top management is there.

One significant trend has been diversity of program. Each year, the range of institutions covered is being broadened. In addition to the larger universities and science schools, more and more aid is going to women's colleges, liberal arts groups, unaccredited four year colleges, junior or community colleges, and publicly as well as privately controlled institutions.

Types of aid are mainly:

1. Unrestricted grants for current operations
2. Capital grants
3. Student aid
4. Grants for faculty and staff compensation.

The attitude toward unrestricted grants has changed greatly in recent years, with some of the major aid to education programs now centered on unrestricted giving. Most of this is probably applied to staff salaries by recipient colleges.

With the patterns of giving to education that have been established, a figure of $500 million a year from 800,000 firms, the Council feels, is not impossible by 1970.

The growth of aid to education programs in some representative companies within the past few years is shown by the table.

	1954	1958	1959
American Cyanamid	$500,000	$758,000	$770,000
Du Pont	730,500	1,173,000	1,318,000
Esso Education Foundation	500,000	1,951,630	1,951,500
General Foods Fund	372,500	413,500	500,000
International Nickel	11,945	295,000	263,000
Procter & Gamble & Procter & Gamble Fund	126,000	930,973	940,000
Shell Companies Foundation	347,000	722,050	759,350
Standard Oil of California	—	709,700	1,470,948
Standard Oil of Indiana & Foundation	528,000	860,000	725,000
Union Carbide & UC Educ. Fund	850,000	1,435,000	1,309,000
Westinghouse Ed. Foundation	309,390	806,450	1,625,000

Note: All figures in this table have been furnished by the respective companies or their foundations. Most are for higher education.

Computers seen as necessity in engineering education

"Engineering calculations of the future will be done by machines," declared recently D. L. Katz and E. I. Organick, U. of Mich. faculty members, in a report to the American Society for Engineering Education. In their opinion, a large capacity computer is almost a necessity for undergraduate instruction in an engineering college of "more than moderate size."

Five percent salary hike for Lehigh chemical engineers

Chemical engineers graduated from Lehigh University this June will receive an average starting salary of $515, up about 5% from the 1959 level of $488. Leading the parade are the electrical engineers with $540, while the class average was $493. Interesting trend—starting salaries for liberal arts gradutes, while somewhat less than for engineers, were up 18%, greatest percent increase for any category.

Chemical industry profits too low

Profits should increase 12 percent to match par. Replacement, not book figures, reflect real plant values, Hercules Powder executive tells Mexico Joint Meeting.

AN OVER-ALL PRICE INCREASE of around 12 percent is necessary in the chemical industry to make profits sufficient. Present profits are much too low, E. B. Morrow told the International Congress of Chemical Engineering in Mexico City. Total chemical and allied industries in 1959 showed a return of 5.1 percent, or 4.3 percent less than their par. This is equivalent to 9.0 percent before taxes on $36,066 million of operating assets, or $3,246 million. Chemical industry sales last year totaled $27,133 million, so that the 12 per cent increase on sales prices would have been required to match the par.

Par should be calculated on replacement value rather than book figures, Morrow says, and this is what he has done. Book figures no longer reflect real plant values, the Hercules Powder executive claims. This is because of inflation and the continued rise in plant construction costs. Book figures are no longer a sound basis for measuring the amount of operating assets of a firm. This figure should include the plant investment at its current replacement cost in order to properly measure a company's performance, since the ultimate test is percent return on investment compared with par for the course.

Based on replacement cost, the basis for par earnings is sufficient to pay reasonable cash dividends on the operating assets employed in the business. It also provides an amount of retained earnings which, along with depreciation reserve set-asides, will finance the growth of his business. While figures on the replacement cost of plant investment are not available in the case of most companies, the reasonable approximation is to increase the published plant book figures by 69 percent.

Unfortunately, since the government allowance for depreciation is based on book rather than replacement cost, a higher proportion of expansion funds at present has to come from retained earnings. The result is to boost the needed return on operating assets at replacement cost after taxes. And the only kind of profit worth talking about, after all, is after taxes.

Comparative percent returns on operating assets of various industries in 1959 at book and replacement values.

(Figures in Millions of Dollars)

	Chemicals & Allied Products	Petroleum Refining & Related Industries	All Manufacturing Corporations
1. Net sales—1959	$27,133	$28,591	$337,817
BOOK VALUE			
Operating assets @ cost start of 1959:			
2. Accounts receivable	2,736	3,342	34,181
3. Inventories	3,957	3,403	52,999
4. Plants, property, and equipment	17,381	39,475	169,097
5. Total (a)	$24,074	$46,220	$256,277
6. Net profit from operations	$3,835	$2,520	$28,699
7. After depreciation depletion and amortization of	1,125	2,161	10,280
Per cent return on operating assets:			
8. Before taxes and interest	15.9%	5.5%	11.2%
9. After taxes @ 52%	7.6%	2.6%* (4.8% after 13% tax)	5.4%
REPLACEMENT VALUE			
(a) Operating assets @ replacement cost after writing up plant 69%			
Per cent return on operating asset:			
10. Before taxes and interest	10.6%	3.4%	7.7%
11. After taxes @ 52%	5.1%	1.6% (3.0% after 13% tax)	3.7%
12. After depreciation depletion and amortization of	$1,125	$2,161	$10,280
13. Per cent depreciation provision of plant at replacement cost	3.8%	3.2%	3.6%

* All figures are on the assumption that operating income is taxed 52%. In the case of petroleum, the SEC figures indicated an average tax of only 13%. Thus, the 3.4% return before taxes would net 3.0% after taxes instead of the 1.6% shown. However, the 3.0% figure is still a very low return.

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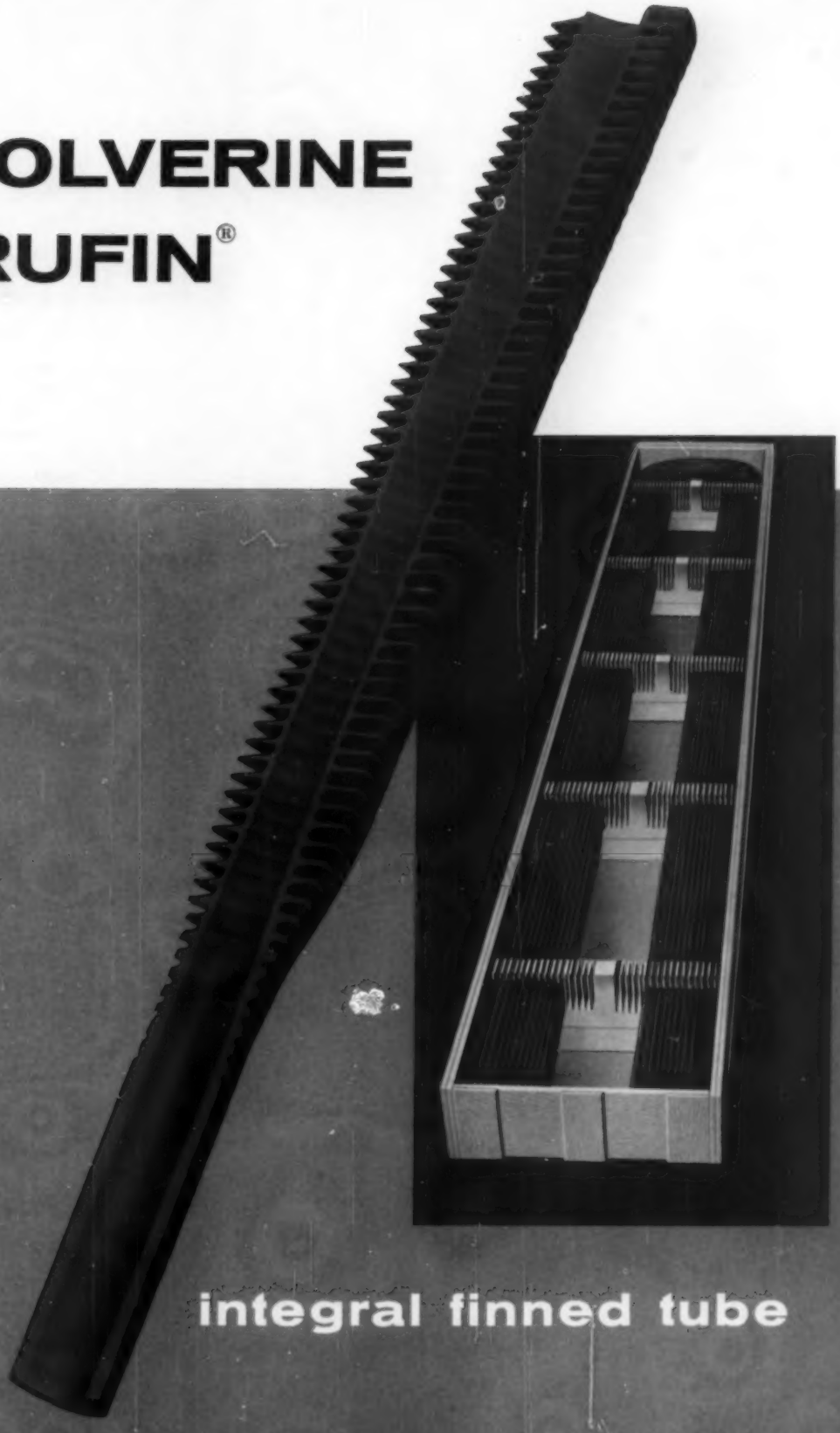

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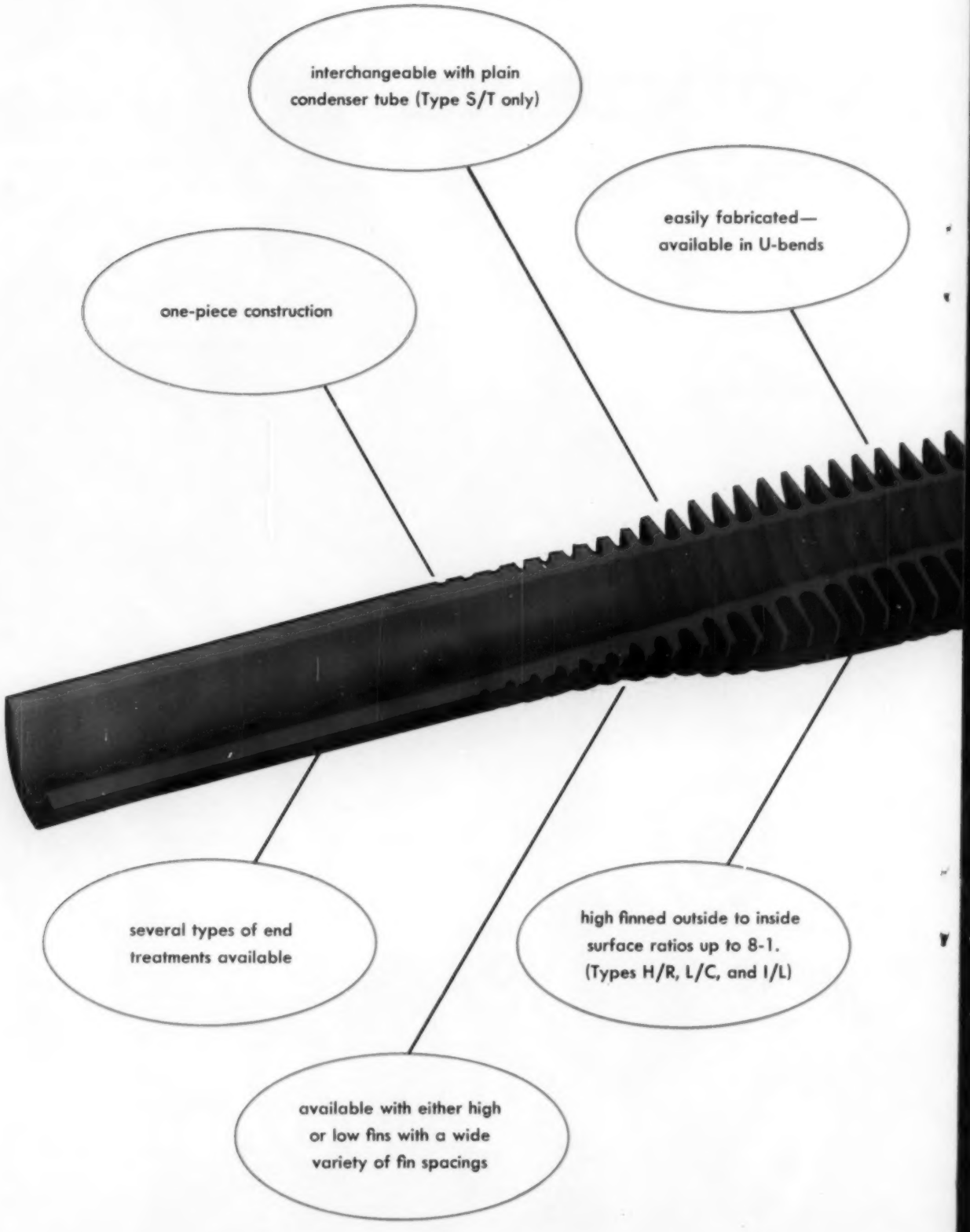
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In addition to a fully staffed Field Engineering Service, Wolverine Tube also maintains Technical Heat Transfer Specialists in all major processing areas across the country. These men have all undergone intensive training in finned tube technology and have completed a Process Heat Transfer Course conducted by Donald Q. Kern, Wolverine consultant.

RESEARCH AND DEVELOPMENT

Wolverine Tube maintains the industry's most complete research and development facilities in Allen Park, Michigan. Here, day-in and day-out, research delving into all aspects of tubing manufacturing is carried out. Extensive research in finned tube and heat transfer has been conducted at the University of Michigan for many years in Wolverine's behalf. You can rest assured, as a result of all of these activities, that Wolverine Tube contributes its full share to the advancement of tubing technology. You can be sure, too, that because of these facilities you can place your complete trust in any product bearing the Wolverine name.

Next time you require finned tube—or have a tubing problem—consult Wolverine Tube. Either way you'll be sure of the finest product or soundest advice available.

Wolverine Trufin is available in Canada through the Unifin Tube Division, London, Ontario.

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Washington scope

The year begins in Washington

AS THIS IS BEING WRITTEN, it's like New Year's Eve in Washington. July 1 is the first day of Fiscal 1961 which is a far more important day to those who are trying to conduct business with the Federal Government than is the first day of the calendar year.

While some industries are complaining, it is generally conceded that the overall volume and profit picture is good and the future is far from glum. It's the erratically changing picture that worries most businessmen.

New bills

Even though domestic business is good, there's much pending national legislation that will have important effects on the chemical and process industries. And no one knows how Congress, driven by the political need to prepare for fall elections, is going to act. The chemical industry will be affected directly by such legislation as defense appropriations amounting to $41 billion, and indirectly by such legislation as school construction amounting to $1.3 billion.

A segment of the chemical industry concerned with color additives for food and cosmetics will likely be faced with more problems in conforming to the requirements of H.R. 7624, now before the House. This bill, unlike S. 2197 which passed the Senate and now lies dying in the House, requires manufacturers to submit, to Food and Drug Administration, evidence of the safety of color additives when used in specific amounts in specific end items. No color additive is considered absolutely harmless, but FDA (with the aid of a committee it will appoint from a group of scientists nominated by the National Academy of Science) will accept or reject proposed quantities of specific coloring materials for use in specific end items. Passage of H.R. 7624 is considered almost certain.

Typical of the less glamorous bills of major importance to the process equipment manufacturers is Senate Bill S. 3557, introduced by one of the most important men in Congress, Senator Lyndon Johnson. This and parallel bills in the House provide badly needed additional funds for the further development of economical processes for producing fresh water from sea water. (See *CEP*, June, 1960.) Well-informed people in the process industries are aware that the 240 billion gallons of water we now use daily are not adequately meeting our needs. They further realize that there are no known fresh water sources to supply the 500 billion gallon predicted national requirement in 1980. Economical sea water conversion processes would, they feel, provide welcome relief for this growing shortage. But we are just beginning to appreciate how much such processes could mean to American business if used to benefit water-short foreign nations.

Foreign aid

Water is only one of the many things that our foreign friends need. The fact that Congress has already passed $4.1 billion in authorizations for foreign aid indicates the importance our legislators attach to the demands placed upon the U.S. by needy nations. The existence of the Development Loan Fund, the Export-Import Bank, the International Cooperation Administration, and the World Bank (International Bank for Reconstruction & Development), is further testimony of the need for help to potential allies. Almost every segment of Government in Washington evaluates things today on the basis of world reaction rather than on national needs alone. Official and

continued on page 24

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AVAILABLE IN ALL STANDARD LENGTHS UP TO 143"

SEVEN INCHES WIDER—Yes, the new 29" wide Dean Panelcoil is a full 7" wider than the previous 22" industry maximum. This extra 7" will, in many cases, enable you to use one or two fewer Panelcoils on a given heating or cooling job. Result, fewer fittings, less connecting pipe and most important of all, less labor.

Dean Panelcoil has additional dollars and cents savings for you. Its initial cost is usually much less than old-fashioned pipe coil or jacketing. It weighs less. Uses less space. In fact, it is better in almost every way.

Dean Panelcoil is made by seam-welding two sheets of metal together, one or both sheets being embossed to form the flow channels. Get the whole story—Dean Data Sheet 15-60 Series and Price Bulletin 259.

Single Embossed Double Embossed

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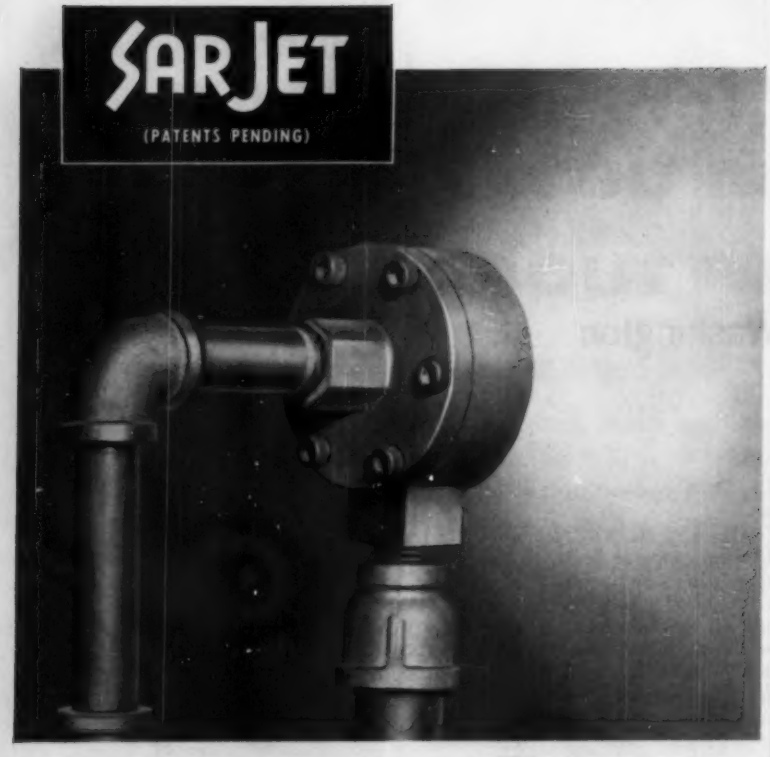
1040 DEAN ST., BKLYN 38, N. Y.
STerling 9-5400

Backed by 25 Years of Panel Coil Manufacturing

For more information, circle No. 26



Can SARJET Help YOU?

Here is an atomizing spray head, entirely new in design. It is simple, compact, precision engineered, inexpensive. It can be engineered to use one, two or more fluents in combination with one medium which is under pressure — steam, compressed air, other. It delivers a fog-like mist with no fall-out of moisture whatever. This fog is easily blown and guided through various machines, wherever a product requires a steady degree of humidity in processing.

There are no moving parts in a SarJet. Its turn-down range is unusually wide, without any sacrifice of atomizing efficiency. It is as nearly foolproof as anything can be, needs cleaning infrequently and, when being cleaned, is disassembled in less than a minute.

Originally designed by SARGENT for "ordering" tobacco (the delicately exact process of restoring moisture to dried tobacco for further processing), the basic SarJet uses compressed air or steam, with water. It delivers a flat, horizontal fan of fog-like mist from two to six feet wide and three to ten feet in length. It can be engineered to deliver any spray-pattern desired. Its uses are apparently limitless. We do know that wherever there's need for moisture regain *in* a product, not *on* it; wherever a high degree of humidity is used; wherever there is need for a fog composed of two or more fluents intimately mixed, SarJet will serve dependably, economically.

Can SarJet help YOU?

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Washington scope

from page 23

unofficial Washington are sold on the philosophy that our survival, and the survival of the civilized world, depend on the unified strength of the western world, that a war means total destruction regardless of who wins, that we must not, therefore, fight, and that we can avoid fighting only by remaining so strong and so alert that our enemies can see no chance for victory. No end is seen to this armed stalemate. Hence, no price seems too great to gain or hold an ally.

Lower tariffs

The willingness to meet all the foreign competition of both friend and foe, without the benefit of tariff protection, is becoming a more and more important part of our national philosophy. The old "Buy American" slogan is rapidly being displaced by "Buy Abroad", "Sell Abroad", "Manufacture Abroad", "Invest Abroad". As indicated on this page in May *CEP*, concern has been expressed in Washington about the apparent apathetic attitude of the chemical industry toward the General Agreement on Tariffs and Trade (GATT) Conference to be held in Geneva next September. The notice of public hearings to be held here in Washington starting July 11th, has been issued by the Interdepartmental Trade Agreements Organization Consisting of the Departments of State, Treasury, Defense, Agriculture, Commerce, Labor, Interior, the U. S. Tariff Commission and the International Cooperation Administration. But American industry is just beginning to show real interest. Manufacturers having both domestic and foreign plants that produce the same product are said now to be exhibiting considerable frustration. Our government, too, has its problems in attempting to make international commercial efforts effective in providing for national security. India's new chemical and process plant program, for example, includes help not only from the U.S. and West Germany, but also from the U.S.S.R. and East Germany.

Unquestionably, the psychological atmosphere in Washington today is like that at half-past eleven on New Year's Eve—jovous, but bewildered. And out of this confusion business headaches will certainly grow to worry the chemical industry at least through 1961.

—Jos. L. Gillman, Jr.

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WESTON "UNITIZED" CONSTRUCTION

PEAK PICKING RECORDER FOR GAS CHROMATOGRAPHY SPEEDS ANALYSIS... SIMPLIFIES PROCESS CONTROL

Weston Peak Picking Recorders are now serving the chemical and petroleum industries in critical applications for gas chromatography. They are also valuable for other uses where peak height is an important factor.

Simplified analysis is provided with the Model 6707 Recorder since only peak heights are indicated. Successively numbered points are printed on a *slowly* moving chart. Result: many hours of stream data are immediately available for study in the recorder window.

Extremely versatile, this multi-point instrument can handle as many control and transmission signals as there are stream components. And it is often used in conjunction with control systems, data loggers and computers. It can be fitted to protect against disappearing components and false peaks.

Other features include electronic peak detection; plug-in amplifier; easily replaceable range standards; and an exclusive D-PAK (T.M.) that eliminates standard cells, batteries, and standardizing mechanisms. The compact recorder is housed in a rugged, dust-resistant case which permits universal mounting—panel, wall or table.

Ask your local Weston representative for complete information on the Peak Picking Recorder and other instruments for industry, or write for Catalog 08-101. Weston Instruments Division, Daystrom, Inc., Newark 12, New Jersey. *International Sales Division, 100 Empire Street, Newark 12, New Jersey.*
In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ontario.

Available in 2, 10 or 20-second carriage speeds across full 10-inch scale. Points: 2, 3, 4, 6, 8, 12. Chart speeds: Multiple—1 to 24 inches per hour; Single—24 to 960 inches per hour. Operation: 115 volts, 60 cycles; or 115 volts, 50 cycles. Optional features include: alarm contacts, pen dragger, and time operation pen.

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WESTON INSTRUMENTS DIVISION

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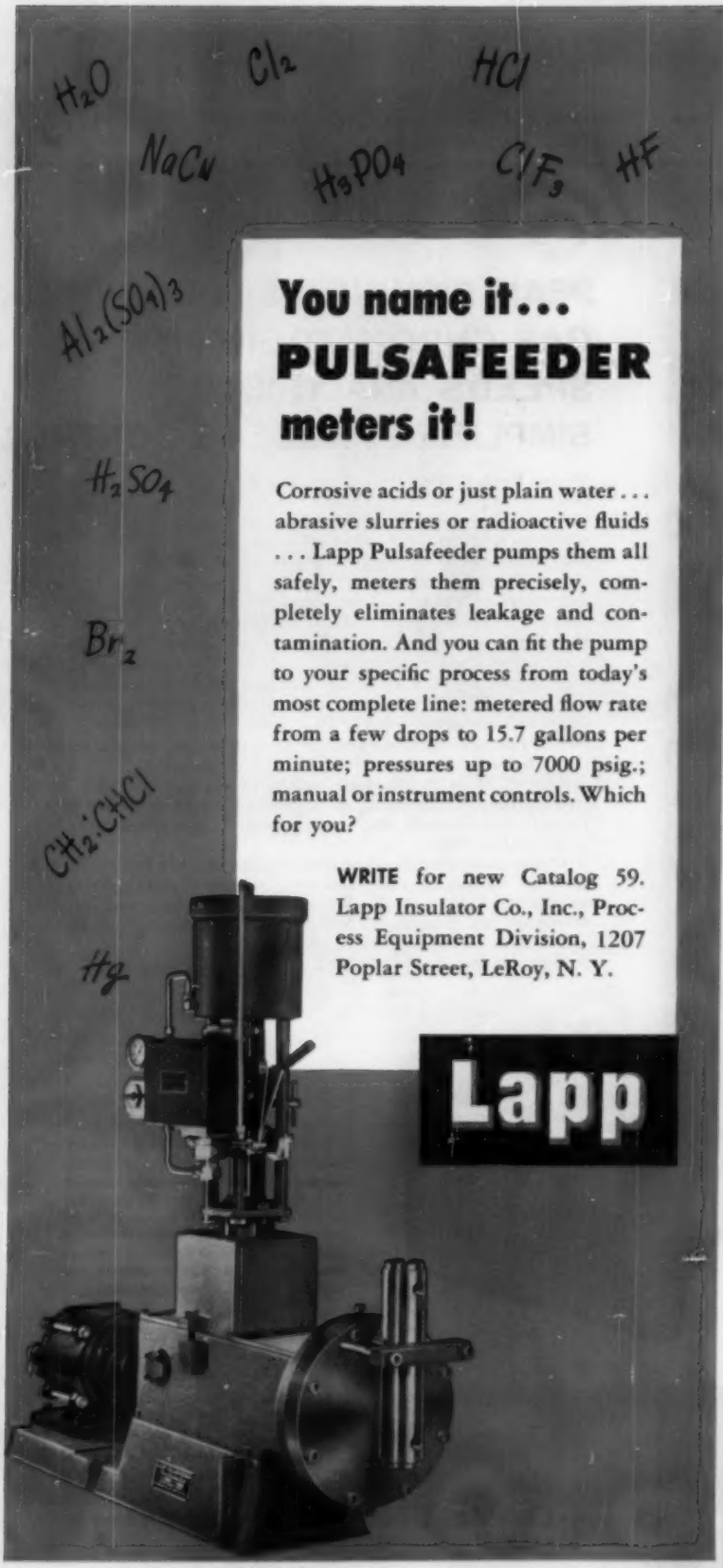

letters to the editor

Georgia Replies to Sherman

Here is the reply of Dr. Harrison, president of Georgia Tech, to the letter of P.S. Sherman in the June CEP.

I was amazed at the energy expended in castigating both Mr. Resen and me in your letter (June *CEP*) but I appreciate it. I am sorry you did not hear my talk; perhaps some misunderstandings would have been averted.

The problems of which I spoke were not intended to be those of Akron or of any other specific geographical area. Admittedly, there are excellent schools and school systems all over America, occasionally adjacent to very poor ones. Nevertheless, thousands of American high schools do not even offer mathematics, physics, and chemistry at a level to equip the student for college entrance.

Many small schools, even some of those in Ohio where I formerly lived, do not have the demand for such courses to merit paying for a faculty to teach algebra I and II, trigonometry, biology, physics, chemistry, and foreign languages. It was my suggestion that local industries assist such schools by lending teachers from among their qualified employees. Please, therefore, re-read the first sentence in the first paragraph of the editorial at the top of the second column, and particularly note the last six words (April, *CEP*).

And Mr. Sherman, please re-read the two sentences near the bottom of column one which state, "The teacher must know the *content* of the subjects. Having an educator's background *per se* is not enough." I did *not* imply, nor did I state, that subject competence is qualification enough. I stated, and so did Mr. Resen, that "an educator's background *per se* is not enough." It isn't.

With respect to merit pay, there is at least one college which has no automatic increases and no automatic promotions, and yet has attracted a fine faculty. I believe I explained in my talk the simple procedure that is followed. It was probably so obvious that Mr. Resen did not think it necessary to mention. I shall be most delighted to go into it in detail with

continued on page 30

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SPIRAL CONDENSERS ON TOP

Our new Series "G" condensers are designed for installation as the top section of a column or for direct connection to the vapor outlet nozzle of a vessel.

Economy is obvious in the elimination of elaborate supporting structures, large diameter vapor lines and other auxiliaries essential to conventional designs.

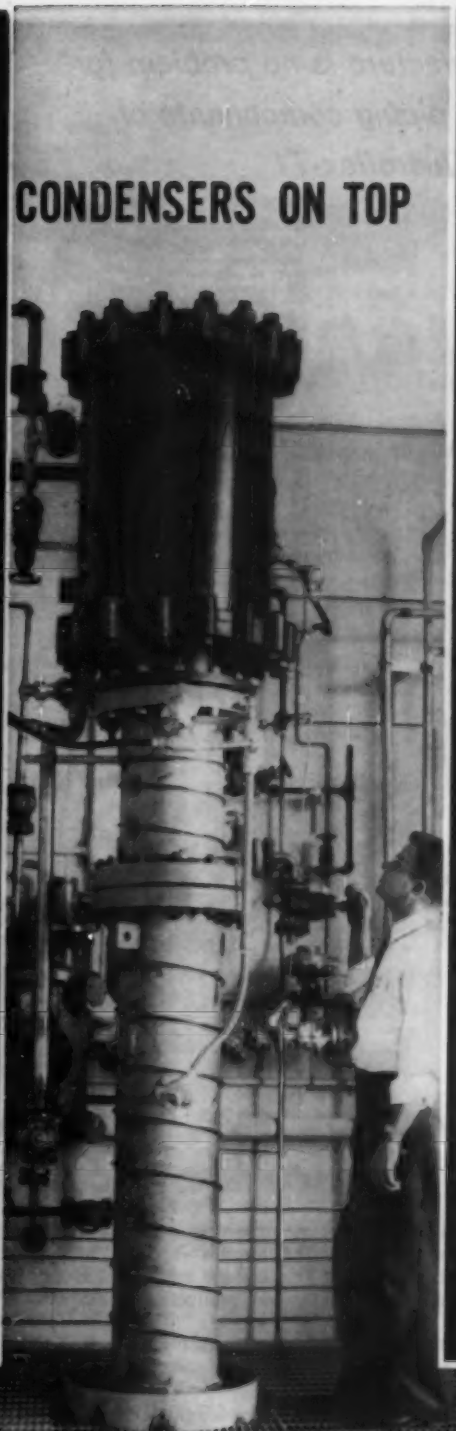
None of the exclusive features of the Spiral condenser have been sacrificed for this direct mounting arrangement. The vapor path can be full counter current spiral flow, combined cross flow-spiral flow or full cross flow. Any combination for maximum or minimum cooling of condensate and noncondensables can be obtained in the in-built after-cooling zone.

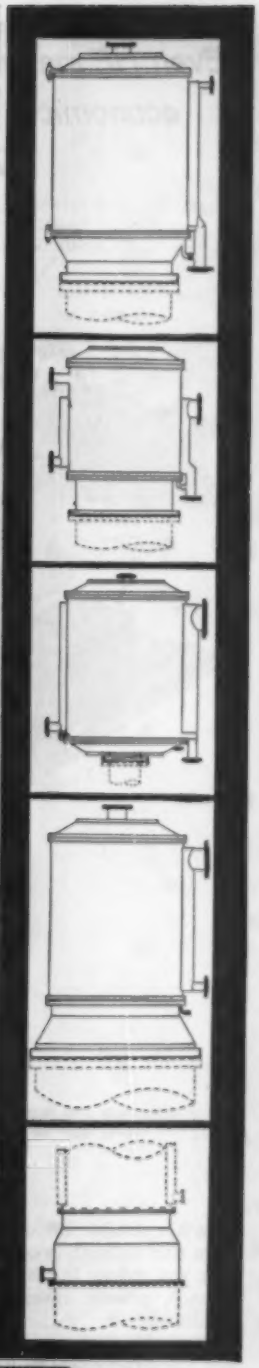
The Spiral condenser is unequaled for stripping out soluble gases. The rapid and complete separation of condensate from fixed gases prevents partial re-absorption, and separate outlets are provided for the condensate and the noncondensables.

The Spiral is furnished for either total, partial, reflux, vent or knock-down condensing services in sizes from 15 sq. ft. to 1600 sq. ft. and for design pressures up to 150 p.s.i.g. Large volume condensate retention capacity can be incorporated when desired.

Spirals are fabricated in any material that can be cold formed and welded to ASME Code requirements.

Write for full particulars.





a h r c o

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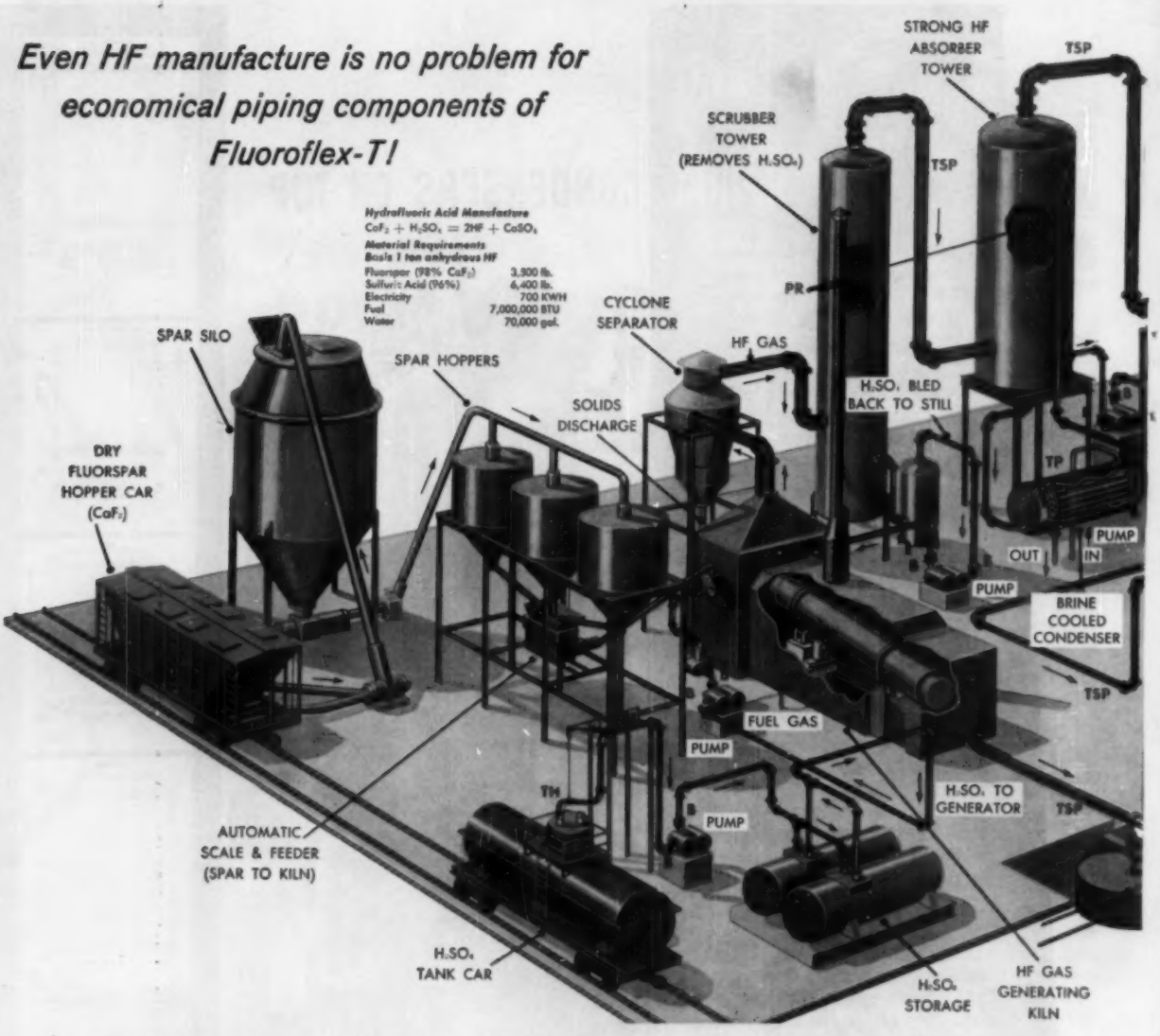
Even HF manufacture is no problem for economical piping components of Fluoroflex-T!



NOW AT LAST, for all your corrosive of long-life, corrosion-

Now it is possible for you to pipe your entire corrosive process from start to finish in corrosion-impervious Fluoroflex®-T, to save you money in faster installation, and decreased maintenance, process downtime, replacements, and production headaches!

Fluoroflex-T, the proprietary Teflon® product manufactured and fabricated solely by Resistoflex, combines two important elements:

1. The widely-known corrosion-imperviousness of Teflon; complete resistance to *any* chemical (except high-temperature fluorine and the molten alkali metals) up to 500°F.!

2. Optimum flexibility, density, strength, and flex-life; nonporosity and structural uniformity; all imparted by Resistoflex's superior fabrication techniques.

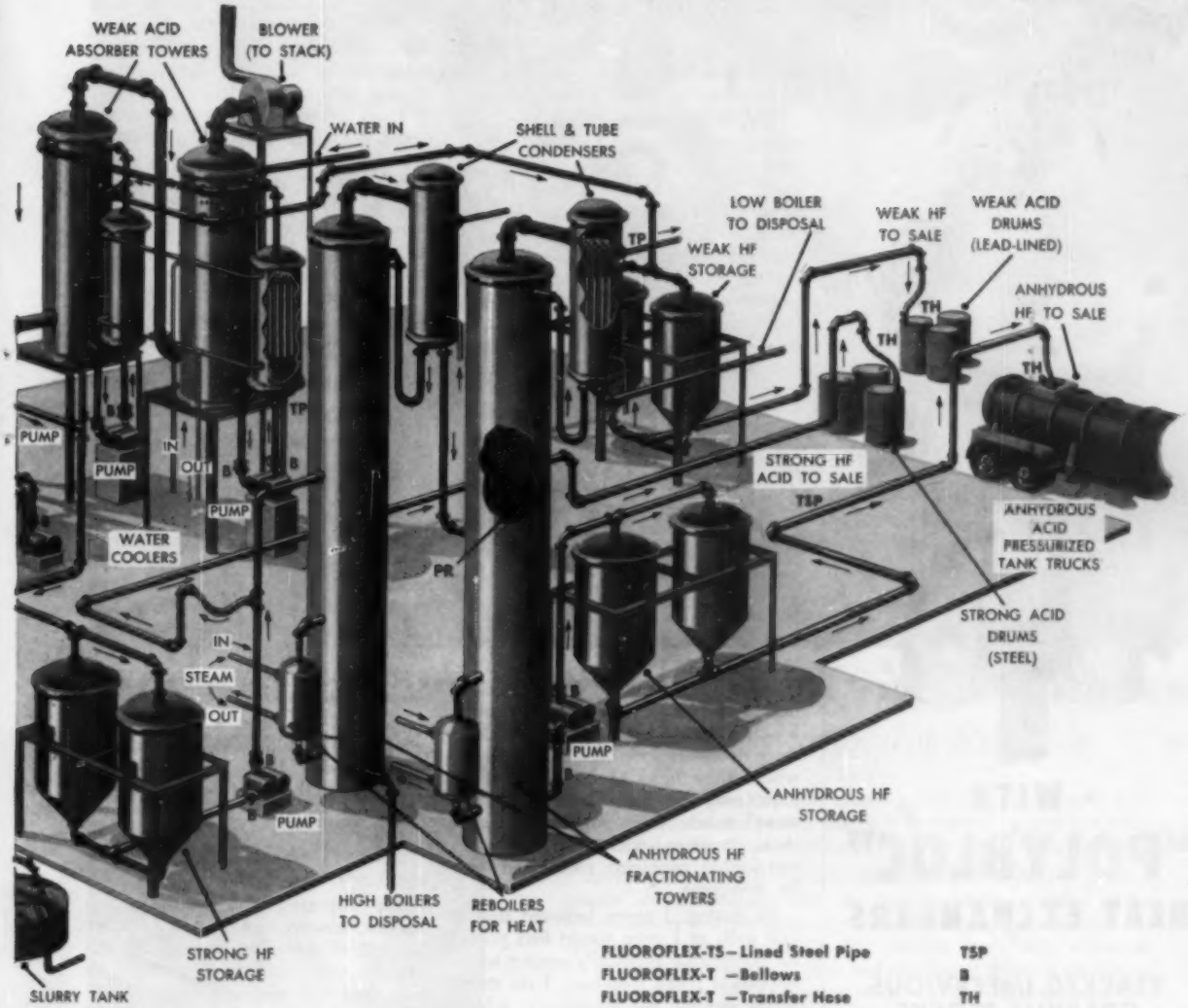
As to the kind of economies possible, one plant equipped with Fluoroflex-T reported savings of $60,000 per month in costs of maintenance, downtime, and product loss!

This in addition to installation economies. The Fluoroflex-T family of corrosion-resistant piping components (see panel at side) have all been designed for complete couplability and hookup ease, in a complete range of sizes to fit any flow, process, or process path.

If *you* have problems of handling corrosive fluids—in cost, equipment maintenance and replacement, process downtime—why not talk them over with Resistoflex? As they have for others, their fully experienced staff of engineers and equipment specialists may be able to save *you* money, time, and headaches! Write for Bulletin today!

Check These Versatile Fluoroflex-T Piping Components for Economy, Installation Ease, Long Process Life!

Fluoroflex-T Lined Steel Pipe: Prefabricated to section lengths, conforming to your blueprint specs, with flanges on and ready to assemble. Minimizes assembly time; shortens checkout time; suitable for all fluids; complete series of fittings and connections available.



FLUOROFLEX-TS—Lined Steel Pipe	TSP
FLUOROFLEX-T —Bellows	B
FLUOROFLEX-T —Transfer Hose	TH
FLUOROFLEX-T —Tube Protectors	TP
FLUOROFLEX-T —Raschig Packing Rings	PR

piping problems, the overall economy proof FLUOROFLEX-T (TEFLON)!

Chemical Transfer Hose: Completely resistant to corrosion; long flex life; available in rubber or stainless steel braid coverings. The answer to all your flex hose problems!

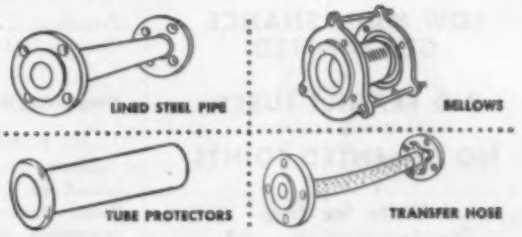
Molded Bellows-Flex Joints: Up to one million flexings without detectable deterioration! Adjust to longitudinal and temperature movements, damp out equipment vibrations. Molded rather than machined, their built-in flex-life can add years to the life of your piping and equipment!

Dip Pipes, Spargers, Thermowells: For non-corrosive nozzle openings, steam nozzles, instrument wells in process equipment.

Condenser Tube Protectors: Eliminate erosion and corrosion of high-velocity acid in entry side of condenser tubes.

And also:

Fluoroflex-T Tower Packing Rings: Light in weight, durable, corrosion and erosion resistant, these economical Raschig rings have only one-fourth the weight of monel rings! Next time you need tower packing, check on these to simplify your tower design, costs, maintenance problems!



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Complete systems for corrosive service

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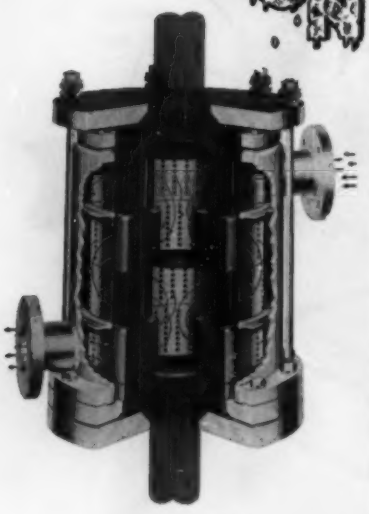
BEAT
CORROSION

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Letters to the editor

from page 26

you if you wish. It was not omitted as an effort to "throw rocks and run."

May I add, further, that I am not surprised that you had in college very few teachers who were "any good as teachers," although well qualified in subject matter. Only a small proportion of any profession is really good, and I am certain that this statement is true both of your public school teachers who have been taught how to teach and of those who have only "subject competence." Since this is pure opinion, I did *not* say it in my talk. However, I pleaded for *both*, as Mr. Resen reported.

I am sorry, too, that your "part-time service has never proven at all satisfactory." If you are interested, I can easily furnish you the name of an outstanding grammar school in California where the part-time use of subject-matter scientists from a nearby University has worked near-miracles. It has proven overwhelmingly successful both in teaching teachers and in teaching their pupils.

Frankly, it is my hope that in talking to groups of professional people I can arouse in them some of the drive necessary to bring about changes where they need to be made. Perhaps, *only* the "merit system of payment" needs their support in *your* area. Perhaps, with their help the formidable problems mentioned can be overcome.

In closing, I never believed that a talk such as I gave would find popular acceptance especially among some education board members. I do stand firmly behind my statements, which are not "poetic license," "uninformed," or guilty of having been "generalized too much on inadequate data."

I congratulate you on having already solved some of your problems. May you continue to move forward.

DR. EDWIN D. HARRISON

President
Georgia Institute of Technology

Sweetening the kitty

To the Editor:

There are many members who would be glad to contribute additional money toward some of the operations of our National Institute. A Contribution Committee has been selected by the National Council of A.I.Ch.E. It consists of John J. McKetta, chairman, Roland Voorhees and Donald A. Dahlstrom (all three are National Council Members).

This committee will try to raise money by the simple means of asking the membership to chip in whatever extra money they can during dues-paying time.

There are many things that the National A.I.Ch.E. would like to do in order to be more useful to its membership. The National Council is continually studying this question. The principal problem is money. If we can help it, we do not want to raise the dues because this might impose a hardship on some of our younger members. It would also adversely affect our efforts to attract new members.

We know that many of our members are in a position to pay a little more, and we think that nearly all of you would be willing to make a voluntary annual contribution. Money received this way will be placed in an unrestricted fund, the application of which will be determined from time to time by the Council. Because conditions do change, we don't think it would be wise to have this money earmarked for specific purposes. Furthermore, the best uses to which the money can be put will depend upon the amount of money available.

You will be given a choice as to what you would like to see this money spent for. The committee hopes that this method of raising additional money will work because it will enable us to do some of the things that you would like to see the Institute do for you.

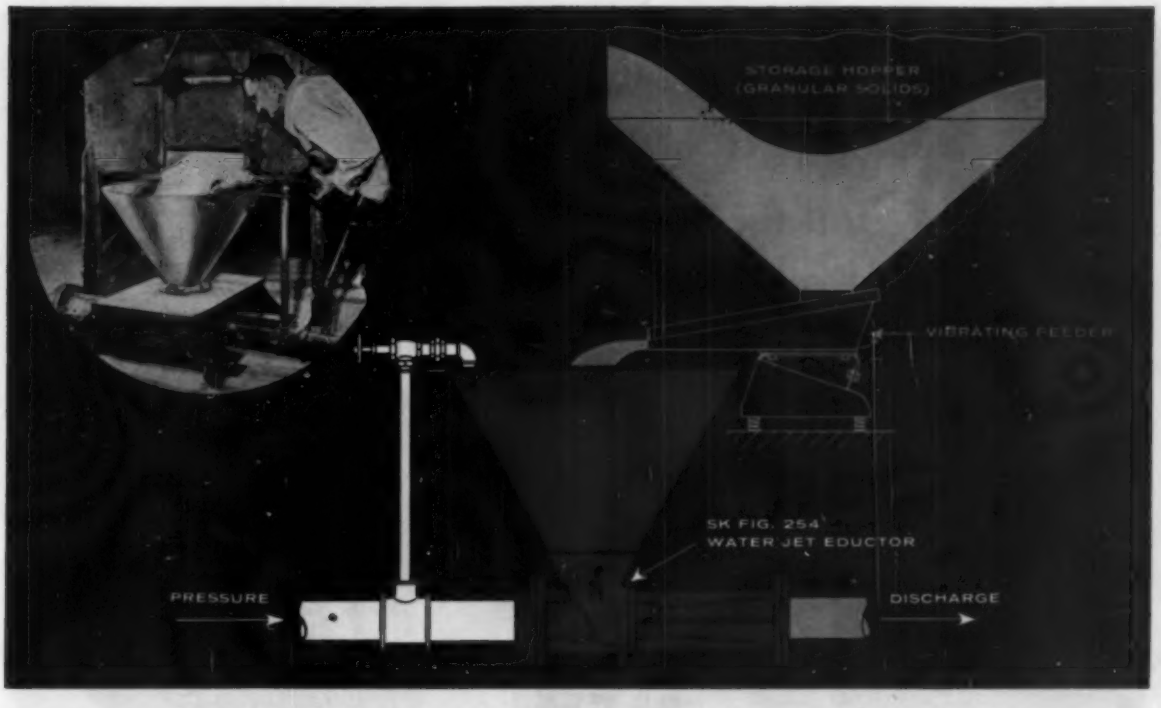
The important thing is that any amount, however small, will help. At the end of the year, simply add the amount you wish to contribute to your dues and send in a single check.

Some of the things that we would all like to have done, although we can't guarantee that any of these things can be done unless the money is available, are as follows:

1. Add a man to the National staff whose sole responsibility would be helping the Local Sections. He would also be of some assistance to the Student Chapters. Among other things, he would assist in arranging for speakers and perhaps speakers' tours for the Sections and the Chapters.

2. The A.I.Ch.E. would like to improve the employment services offered to the membership either through the Engineering Societies Personnel Service or by other means.

continued on page 32



MIX SOLIDS WITH LIQUID, CONVEY SLURRIES

with this SK "Hopper Type" Water Jet Eductor

SK Fig. 254 Hopper Type Water Jet Eductor

SK's Hopper Type Eductor, shown above and at left, will mix solids with liquid and convey slurries conveniently and at low cost. See box below for types of granular solids currently being handled.

An inexpensive unit, this light-weight eductor is easy to install, simple in construction with no moving parts, requires little maintenance, and provides efficient service over long periods. In operation, pressure water, issuing through the nozzle, entrains granular solids from the hopper and discharges through discharge piping. Agitating jets keep material moving down into the eductor.

Used in the petroleum industry, in chemical processing and food processing plants, the hopper eductor has proved to be extremely satisfactory in handling the materials (bulk densities noted) listed below and others.

For full details on Hopper Type Eductors including sizes, capacities, ratios, water consumption, materials of construction, write to SK for Bulletin 2M.

SK HOPPER EDUCTORS ARE BEING USED CURRENTLY TO HANDLE THE FOLLOWING MATERIALS *(Approx. Bulk Densities Indicated in Parentheses)*

Borax (50-55)	Fly Ash (35-40)	Sawdust, Dry (13)
Charcoal (18-28)	Rosin (67)	Soda Ash, Light (20-35)
Diatomaceous Earth (10-20)	Salt, Granulated (45-51)	Sodium Nitrate, Dry (80)
Lime, Pebble (56)	Salt, Rock (70-80)	Sulphur, Powdered (50-60)
Lime, Powdered (32-40)	Sand, Damp (75-85)	Wheat (48)
Mash (60-65)	Sand, Dry (90-100)	Zinc Oxide, Powder, Dry (10-35)

JET APPARATUS: Ask for Condensed Bulletin J-1.
ROTAMETERS & FLOW INDICATORS: Ask for Condensed Bulletin M-1.
VALVES: Ask for Condensed Bulletin V-1.
HEAT TRANSFER APPARATUS: Ask for Condensed Bulletin HT-1.
GEAR PUMPS: Ask for Bulletin G-1.

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Letters to the editor

from page 30

3. The A.I.Ch.E. would like to publish more technical papers, either in the *Journal, Chemical Engineering Progress*, or other publications.
4. We would like to increase coverage in some of the Institute's publications of non-technical matters of interest to all of the membership.

Your contribution can help a lot. If you have any questions, you may write to any of the members of the Contribution Committee.

JOHN J. MCKETTA
Chairman
Dept. of Chemical Eng.
University of Texas

A most worthy cause. The better the response, the better job the A.I.Ch.E. can do for you.—ED.

Air-Ammonia notes

To the Editor:

I am sure that we all appreciate your cooperation, and the amount of work you and your staff have done to complete this fine job in the time required.

There are a few errors. On page 42 of the May issue the names under the pictures have been interchanged. Mr. Stockbridge's picture has Mr. Hugill's name under it and vice versa. On the lower half of page 41, line 15 in column 1, the units should read, "One cubic centimeter per liter" instead of, "One cubic meter per liter." The information in the box in the first column on page 40 is not quite correct. The 14 names are all right, but the organization is not quite correct. I was chairman and Gordon Weigers was the assistant chairman of the *symposium at St. Paul*, not the subcommittee. The chairman of the *subcommittee* was E. Harold Culp, and his assistant chairman was Harold Maune.

Otherwise, I believe this publication is a fine presentation of the material covered, and remarkably free of errors.

W. A. MASON
Engineering Dept.
Dow Chemical Co.
Midland, Michigan

Mr. Stockbridge, meet Mr. Hugill. —ED.

MILLIONS OF DOLLARS CAN BE SAVED

Struthers Wells

STANDARD HEAT EXCHANGERS

Standard heat exchangers are suitable for a wide range of services, including heating, cooling, vaporizing and condensing, with the maximum usefulness in the smaller sizes.

Standardization of mechanical design and price offers many important advantages to the user.

Savings may be realized in the user's engineering time, due to ease in procurement, inspection of fabrication, checking drawings and construction details.

In plant layout work, the size of the unit can be quickly established, and the complete information available allows exact details to be fixed at once.

Immediate delivery on most units often results in important savings, due to early completion of the proje Interchangeability allows reuse of the equipment in other services, and increases salvage value.

Important cost savings are available to the user, due to economies in manufacture.

Savings to the process industries, by heat exchanger standardization, are estimated at several million dollars annually.

Struthers Wells has just issued a new bulletin, giving complete mechanical design and prices, covering a number of standard sizes, to about 1200 square feet of surface, and in six principal types.

Thermal design data are included in the bulletin, to allow the user to fix the size of the required unit, in various services.

A large stock of standard exchangers allows immediate shipment, in most sizes. Equipment is available in carbon steel, also with non-ferrous tubes, and in stainless Types 304 and 316.

Complete Guide

to the selection of a standard SW Heat Exchanger is contained in Bulletin B-20. Write for your copy today

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Crystallizers . . . Direct Fired Heaters . . . Evaporators . . . Heat Exchangers . . . Mixing and Blending Units . . . Quick Opening Doors . . . Special Carbon and Alloy Processing Vessels . . . Synthesis Converters

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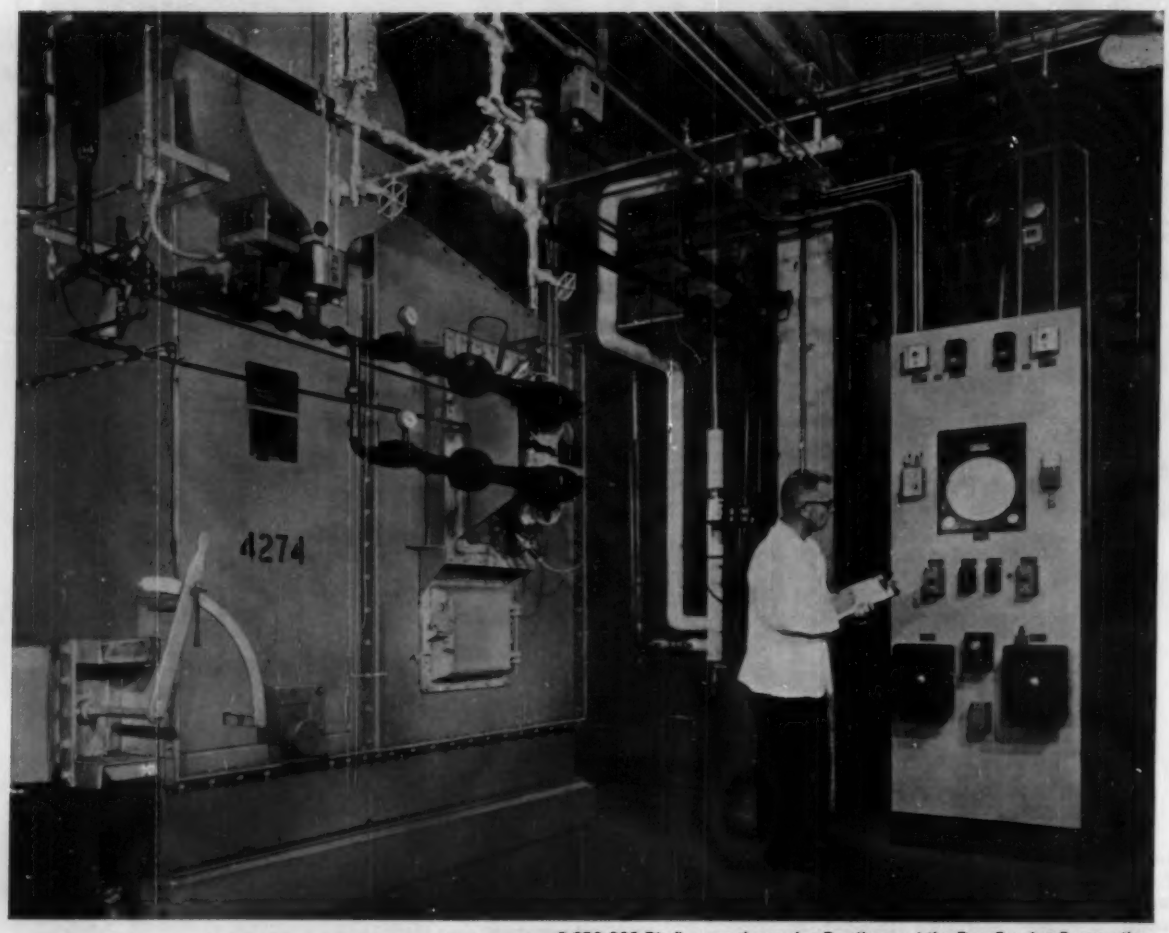

2,250,000 Btu/hr vaporizer using Dowtherm at the Dow Corning Corporation.

PRECISE HIGH TEMPERATURES with COMPLETE SAFETY

NO open flame and NO high pressure steam

In the process industries, obtaining high temperatures without undesirable side effects is a year-round problem. Direct heating with an open flame or heating with high pressure steam often creates fire or explosion hazards. And where precise temperature control is important, they may also result in control difficulties and cost problems.

The answer to these problems is an FW high-temperature low-pressure vaporizer. FW has been designing and building them for 26 years and in that time has installed more than 700 organic process heating systems. Individual units range from 44,500 to 50,000,000 Btu/hr and operate at temperatures from 350 to 750 F at pressures from 1 to 113 psi.

If you have process heating problems, remember that only Foster Wheeler does the complete job. The design of your entire heating system is analyzed to make sure that the application, piping arrangement, and thermal design are correct. And FW not only designs and builds the vaporizer, but also installs the unit and places it in service at top efficiency. In addition, FW engineers are available to work with your consultants and engineers to solve future problems concerned with process changes, relocation of equipment, and plant expansion.

For your high-temperature low-pressure heating problems draw on Foster Wheeler's long and varied experience with vaporizers and process facilities. Many of the outstanding process companies have done so . . . repeatedly. Write for Bulletin ID-54-5. Foster Wheeler Corporation, 666 Fifth Ave., New York 19, N.Y.

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Eliminating the hide-and-seek of indexing

ONE SUBJECT WHICH CONTINUES to generate considerable interest has been the problem of indexing the literature. In recent months, as witnessed by the Letters to the Editor columns, a wide variety of readers have expressed their comments as to what must be done. Before these opinions showed up in print, a hard-working Sub-committee was already making definite strides in a positive direction. The results: a Chemical Engineering Thesaurus to be published next year by A.I.Ch.E., and an improved system for abstracts and indexing terms tied in with articles in *CEP*, the Journal, and other Institute publications. Since the work was done under the auspices of the Standards Committee, it's hoped this Thesaurus-abstracting-indexing-system will be adopted by other publications in the field.

Words, words, words, words

The constantly increasing volume of important technical literature will not diminish in scope nor size. Instead, increasingly complex technology continues to generate more, not less, printed words. In fact, even writing about how to simplify the job adds to the total. The engineer-scientist researcher, trying to benefit from the many published works, is literally inundated with material. He can, of course, be selective in his reading, ask for summaries from his staff, and do much to streamline day-to-day perusal of the literature. It's when he wants to retrieve information on a subject that the situation becomes acute.

In these days when machine computation holds sway, it's easy to say "Why not put it on a machine?" And that, in fact, is the ultimate goal. But it is one which will be approached piece-meal, and will require a major outlay of funds and effort. What can be done now, and preferably be utilized by a lone consulting engineer as well as a large chemical company? This is the question which begs for an answer; one which is forthcoming.

A thesaurus stands as the threshold to a long range indexing system. Use of a "word book" of standard chemical engineering terminology with common synonyms, with technical words of higher and lower generic class, and with words commonly associated, will do much to reduce confusion and misunderstanding. It will facilitate indexing and cross indexing, enable a better choice of terms to be used in indexing and in the retrieving of information. Fortunately, a thesaurus of this nature will not be hard to come by. DuPont Co. has one in existence for internal use, and is releasing it to the Institute to serve as a working core. It will be modified and enlarged, and the final product will be the A.I.Ch.E. Thesaurus, which will then become the standard volume.

Next in line—instant abstracts

Concident with publication of the thesaurus, about mid-1961, the Institute publications will incorporate the new style abstracts and indexing terms for each article in each issue. These are designed to self-classify each article for ready reference and retrieval. The indexing terms use key words and phrases, grouped according to subject and area covered, to describe the article. Here is where the thesaurus will come into real service to avoid conflicts in individual's and companies' utilizing the abstract-index concept.

These actions do not imply that other indexing and abstracting methods are obsolescent or useless. Rather, it's a step in the direction of making as much of the literature as possible adaptable to a universal information retrieval system. The versatility of the contemplated system means it can be expanded to fit in with future developments.

The details on how the abstracts are developed, how they can be used, and the part the thesaurus can and will play in an information retrieval program will be covered at length in articles in *CEP*.

The trend, already noted, is for more words to be spoken, written, and published. The companion action of the publications is to make sure these words, and data, are not sidetracked into the oblivion of a non-working index.

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opinion and comment

Professionalism is a two-way street.

IN NEVERENDING FASHION the subject of professionalism creeps into print, into discussions, and into thoughts. And rightfully so. For the attitude of the individual towards his job is truly all-pervading. Dissatisfaction with it, or his profession, can directly or indirectly affect a present or future career, disrupt an organization, and put a damper on home life. Regardless of the complaints of riding an editorial horse to death, professionalism is a subject which won't lie dormant.

Latest analysis of the situation comes from some northern neighbors. The Association of Professional Engineers of Ontario has come out with a treatise on "Professional Recognition." A key to the Canadians' approach is their awareness that such recognition is a two-way street, and they have split their report down the middle. Half is directed to management; half to the professional engineer. Naturally, it behooves each segment to read both sections.

On the one hand

Rapid industrial growth in Canada, says the APEO, has focussed much attention upon the profession, but unfortunately the individual engineer has been overlooked. Result: frustration, mass migrations of trained engineers from one plant to another, loss of efficiencies and economies.

Management, where job hopping is prevalent, often has not provided a climate where engineers can work happily and effectively while retaining professional attitudes. Such a climate says the APEO would include:

1. Recognition of engineering as creative work.
2. Breakdown of work to give the individual a feeling of responsibility.
3. Acknowledgment of achievement by use of professional seal or signature on an individual's specific work.

The foregoing is a core, and embraces factors in daily job routine. A long-range program would include:

A. Facilities for group discussions.
B. Employer-sponsored post-graduate courses.
C. Upgrading of technicians, using professional engineers as instructors.
D. Encouragement of membership in professional and technical organizations. (*Amen, Ed.*)
E. Management-engineer conferences for interchange of ideas.

Other aspects, continues the APEO, would include a good communication system to keep engineers apprised of long-term planning and company policy. The use of "Patent Waiver" is all too prevalent. If necessary, company counsel should give an equal amount of thought to the protection of the employer *and* to the protection of the inventor. One point APEO didn't touch on was the wholesale hiring of engineers in good times and wholesale firings during recessionary periods.

On the other hand

The engineer, however, can't sit back, point to some injustices, and use these as an excuse for not pulling his weight. He has to readily accept responsibility and show a professional attitude, says APEO. As an individual, he is responsible for the success of his own career. He should get to know his company and the economic facts of industrial life. He should learn opportunities for advancement, opportunities for expansion, new products, and technical trends in industry. In short, he can't isolate himself in his narrow specialty. When he has acquired a knowledge of matters such as these, he has, in effect begun fulfilling his responsibility to himself as an engineer, to management as a professional employee, and to his profession.

L. R.

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CEP feature

J. H. Born, Jr., *Foster Wheeler Corp.*
M. L. Jones, *Dupont*

Efficiency of a high temperature vaporizer

A blow-by-blow report on the actual tests to evaluate the performance characteristics of a vaporizer employing an organic heat transfer fluid.

In view of the ever broadening application of high temperature vapor phase heating in chemical processing and the continuing need for higher process temperatures, it is apparent that information on the performance and operation of the vapor generator or vaporizer is of utmost importance. Little data are available to indicate what conditions exist in the relatively small furnaces of such vaporizers. To obtain basic information of this type a series of tests were carried out in a natural circulation vaporizer, employing Dowtherm* as the heat transfer medium, operating with a vapor temperature close to 700°F. The primary objectives were to determine the efficiency of the vaporizer, the heat transfer rates in the furnace and convection sections, and the distribution of the heat absorption between the furnace and convection sections. As an added consideration, these conditions were investigated with two distinctly different types of oil burners.

The test program consisted of three phases (see box): performance, heat absorption, and metal surface temperatures. Each phase comprised a series of three tests at one particular operating load. The operating load was subsequently varied within the design ranges of the vaporizer to cover low, medium, and high operating ranges. Hence, a total of nine test runs were performed with each type of burner. Figure 1 shows the general arrangement of the vaporizer and locates the test connections.

Test methods

The Dowtherm vaporizer tested is rated at a 6-million B.t.u./hr. output. The unit is a standard shop-assembled two-drum oil fired vaporizer. The furnace is 5 ft. wide and 9 ft. ¾ in. deep from the burner wall to the target wall and varies slightly in height from the drum to the section furthest from the drum, averaging about 8 ft. The furnace is lined on the side walls and the roof with 1½ in. O.D. × #11 B.W.G. carbon steel tubes on 2¼ in. centers. The target wall and the front wall have no heat transfer surfaces. The floor of the furnace consists of tile supported on the lower horizontal leg of the "D" tube of the furnace. (The name "D" tube from its configuration with respect to the drums of the unit.)

The convection section consists of 1½ in. O.D. tubes on the same center-

THE TEST PROGRAM

Performance phase

1. Ultimate analysis of fuel oil
2. Heating value of fuel oil
3. Determine exit gas temperatures
4. Analysis of exit flue gases
5. Measurement of fuel oil consumption
6. Combusion air inlet temperature

Heat absorption phase

1. Measurement of gas temperatures adjacent to inside and outside furnace wall tubes at the burner centerline elevation, at five locations between the front and rear walls of the furnace using a high velocity thermocouple probe.
2. Analysis of aspirated gas samples withdrawn from the furnace at the same locations as Item 1.
3. Measurement of furnace outlet gas temperatures and analysis of aspirated gas samples at five locations between the front and rear walls of the furnace.
4. Measure the gas temperature leaving the convection section and analyze gas samples withdrawn from this area.

Metal temperatures phase

1. Install three thermocouples on the furnace face of four inside and four "D" furnace tubes; thermocouples located one above, one below, and one at the burner centerline.
2. On one "D" furnace tube install thermocouples at one-foot intervals along the full length of a "D" tube.

* *Dowtherm is a Registered Trademark of the Dow Chemical Company.*

to-center distance as the furnace tubes. These tubes are expanded or rolled into the upper and lower drums and tie the drums together. The convection section is divided into two passes for the gas flow. The passes are separated by a vertical baffle supported from the top of the lower drum. The gases leave the furnace and then pass through the bottom of the convection section, travel upward through the first pass, cross over the baffle, and pass downward through the last pass.

The total surface in the furnace, based on the outside surface of the tubes, is 409 sq. ft. The total surface in the convection section is 1471 sq. ft. The furnace volume is 387 cu. ft.

The initial series of tests employed an air atomizing burner in which only a portion of the total air required for combustion passes through the burner. The air was supplied by a turbo blower operating at a 16-oz. discharge pressure with a capacity of 1500 cu. ft./min. The oil supplied to the burners was maintained at 7 to 15 lb./sq.in.

The second series of tests was conducted using a fast reaction type burner that employed both air and steam for atomization. The atomizing steam was supplied at 70 lb./sq.in. ga. With this type of burner all of the air required for combustion passes through the burner. The turbo blower supplied air to the burner at 24-oz. discharge pressure and handled 1900 cu.ft./min. The fuel oil pressure at the burner varied between 70 and 100 lb./sq.in., depending upon the firing rate.

The air atomizing burner produced a rather long bushy flame that substantially filled the furnace volume, whereas, the fast type burner produced a short luminous flame that extended no more than 4 to 5 ft. beyond the burner wall.

Three furnace probe points were located on the wall opposite the burners. Two of the probes were located on the same horizontal centerline as the burners and as close to the furnace side wall tubes as possible. The third probe position was located at the bottom of the furnace in front of the tubes forming the screen of the furnace outlet. These probe points were used to determine the gas temperatures and compositions at five points along the depth of the furnace. In the convection area, three additional probe points were installed to obtain gas temperatures and compositions. The front of the unit is considered that wall on which the burners are installed. An additional probe point located downstream of the vaporizer outlet damper was used to determine the exit gas temperatures and composition.

Thermocouples were installed on the furnace side of several tubes which outline the furnace. A total of 28 thermocouples were installed on eight tubes. Four of the tubes were the "D" tubes, and four were the inboard furnace wall tubes. The tubes on which the thermocouples were installed were the 7th, 20th, 32nd, and 45th tubes, numbered from the burner wall. The 32nd tube had thermocouples spaced at 1-ft. intervals along the length of the "D" tube. The remaining tubes had the thermocouples located 6 in. above and below the burner centerline on the side walls as well as above the burner on the roof tubes.

Test instrumentation. Furnace temperatures were obtained using a water-cooled probe equipped with a platinum-platinum, 10% rhodium thermocouple. Gas was aspirated past the thermocouple which was shielded from radiation by means of a Bureau of Mines Type E ceramic shield. Temperatures were recorded on a circular chart having a range from 1000 to 2500°F, with 20°F subdivisions.

The oxygen content of the samples was determined with an oxygen analyzer and recorder manufactured by the

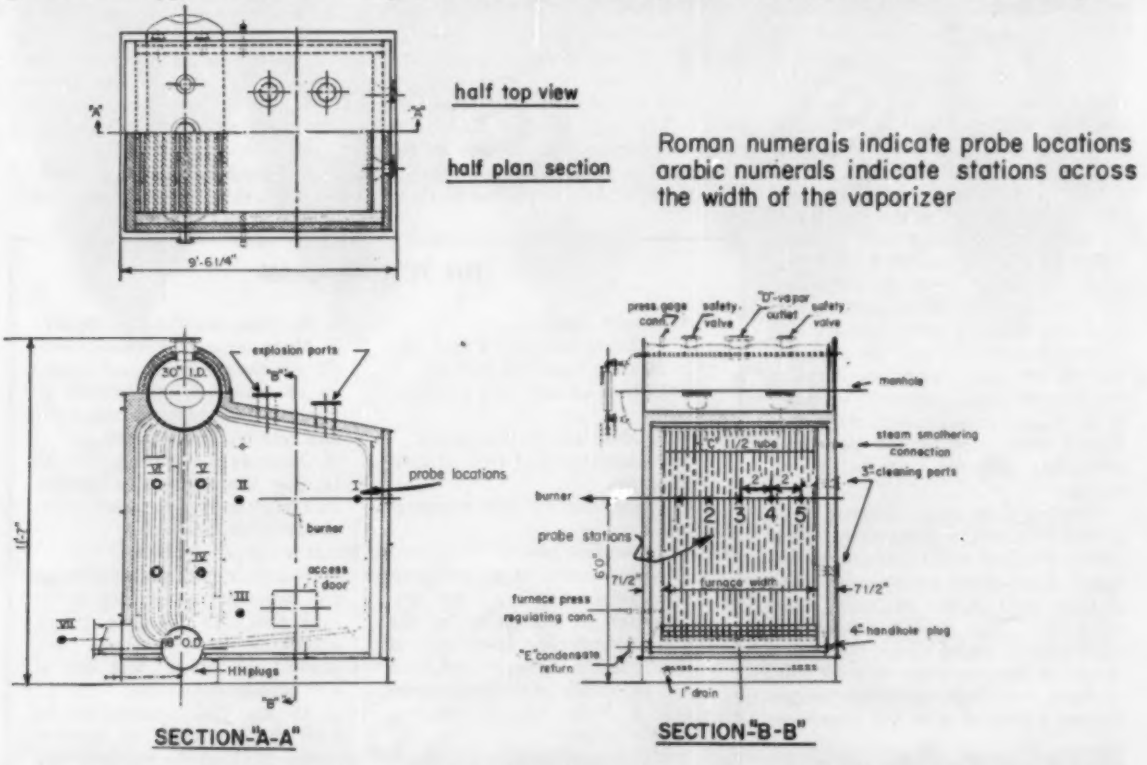
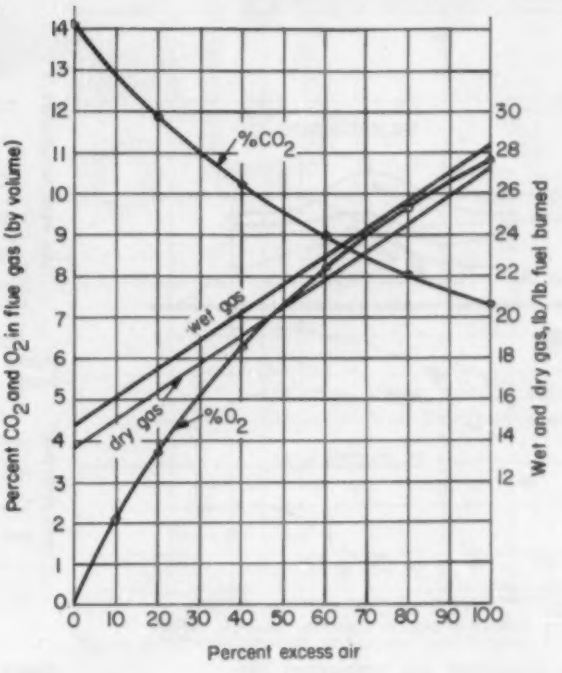


Figure 1. Orthographic sections of vaporizer showing test connections and burner locations.

Figure 2. Combustion curve for #6 fuel oil used in the tests.



Bailey Meter Co. The recording chart had a range of from 0 to 10%, with 0.2% subdivisions.

Gas samples taken at three points across the width of the breeching were analyzed by an Orsat for carbon dioxide and oxygen. The nitrogen was determined by difference. Gas temperatures were also obtained at these locations by the use of chromel-alumel thermocouples. The thermocouple emf's were determined by a potentiometer reading in millivolts.

The fuel oil flow to the vaporizer was metered by an A. O. Smith Co. totalizing type meter. The meter was calibrated by weighing a metered quantity of oil. The fuel oil temperature was obtained by peening thermocouples into the oil pipe lines at the burners. This type of thermocouple was also used to determine the condensate return temperature. The furnace drafts and combustion air pressures were obtained with water manometers.

The pressures and temperatures at which the vaporizer operated were reported by several instruments:

1. pressure gauge on drum (Bourdon tube)
2. pressure gauge on outlet header (Bourdon tube)
3. temperature in upper drum (gas bulb)
4. temperature in outlet header (mercury thermometer)

The four instruments indicated a temperature spread of 20°F. The maximum temperature indicated by the mercury thermometer did not vary during the tests. The minimum temperature was read by the gas bulb in the drum. The pressure gauges indicated saturation temperatures between the two extremes approximately 5°F above the minimum temperature. For the calculations, the gas bulb temperature in the upper drum was used as the vaporizer saturation temperature.

Data was taken once the furnace conditions were stabilized and the condensate return rate was constant, as indicated by a differential manometer. The temperatures in the furnace and convection sections were taken in sequence and in general this consumed the greatest percentage of time and determined the duration of the tests. The excess air was not varied, for the unit was operated to hold a particular furnace draft. During the

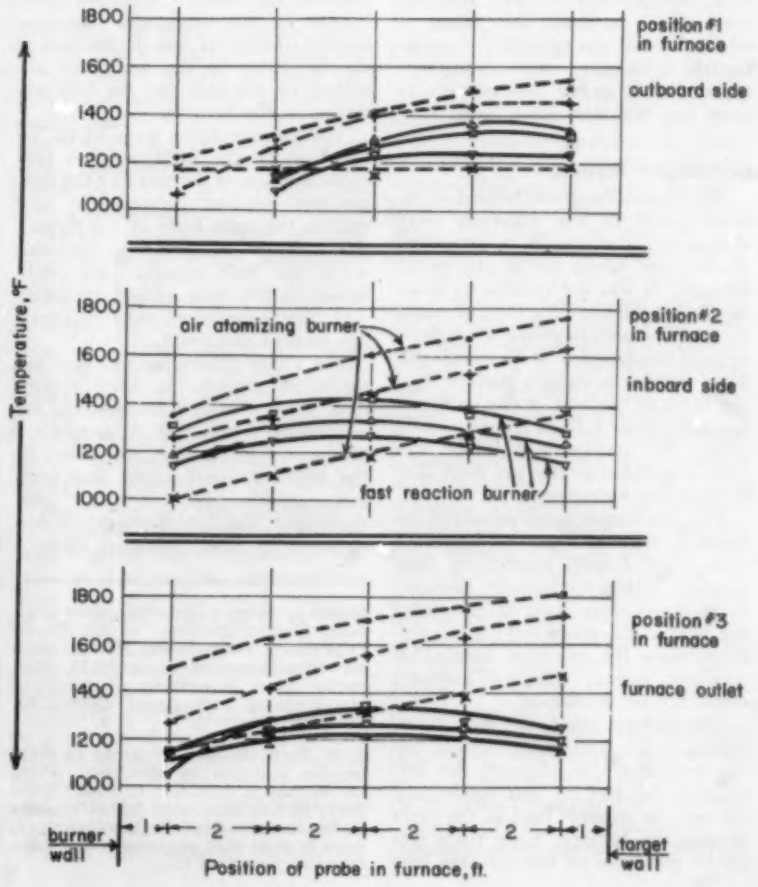


Figure 3. Furnace gas temperatures relating type of burner, load, and probe position.

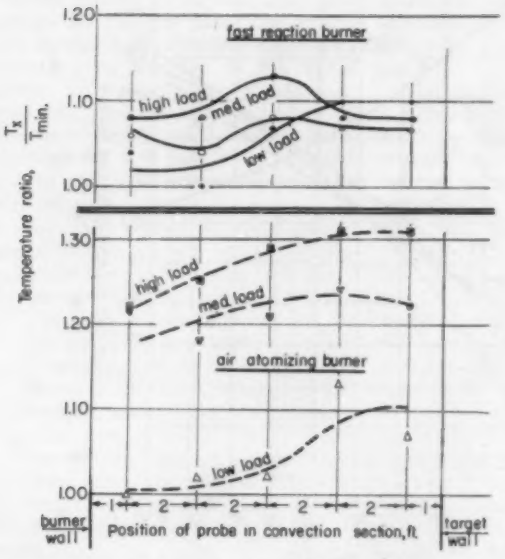


Figure 4. Convection gas temperature pattern: probe location No. 6.

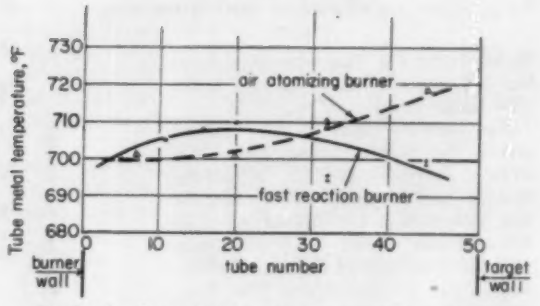


Figure 5. Furnace tube metal temperatures—furnace depth.

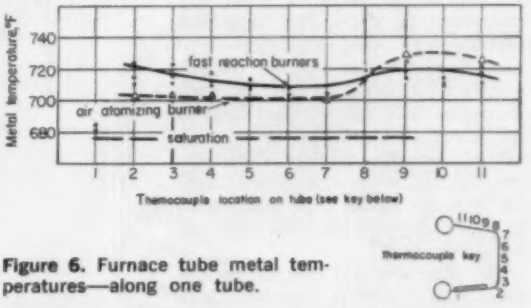


Figure 6. Furnace tube metal temperatures—along one tube.

tests, intermediate oil flow readings were taken to check the rating at which the unit was operating. Approximately 2 hr. were required to carry out each test and it was possible to carry out two tests some days.

Calculation method

Gas compositions determined at various points of the vaporizer were arithmetically averaged to determine the average excess air at any probe location. It was not feasible to investigate the gas flow distribution across the gas flow path to permit a weighted average composition to be calculated. The variation in oxygen percent from the front to the rear of the unit was not more than 1.2% at any one probe point. This average composition was used to determine the gas mass flow through the vaporizer.

The gas temperatures measured coincident with the gas compositions were plotted with respect to their locations within the furnace. Arithmetic averages were used to determine the heat in the gases leaving the furnace. Since the gas flow distribution was not known, weighted averages could not be developed.

The furnace absorption was determined as the difference between the net available heat entering the furnace in the fuel oil and combustion air and the sensible heat in the gases leaving the furnace. Since there was no air preheater on the unit, the heat entering the furnace with the combustion air was negligible. The convection absorption was determined as the difference in the total heat absorbed by the unit and the heat absorbed in the furnace.

The thermocouples installed on the hot face of the furnace tubes provided a means of determining the temperature gradient through the tube wall to the main body of the flowing fluid. When compared to previous work, the heat transfer rate established in this way agreed favorably with that determined from the average furnace absorption.

The vapor generation rate was not measured during the tests though data were obtained to establish the condensate return rate. A comparison of the unit efficiencies, calculated on the basis of input-output and heat-loss methods, did not show good agreement. The condensate return flow obtained by the differential across a pitot tube probably did not represent the vaporizer duty because the exact density and temperature of the manometer fluid (a solution of copper sulfate) used in conjunction with the heat transfer fluid were not known. In addition, carryover and, on some occasions, freezing of the heat transfer fluid in the connecting lines, contributed to the difficulties. Hence the efficiencies based on the input-output method have not been considered to be representative of the true conditions. However, the differential pressure readings were used as a guide in establishing the operating load in conjunction with the fuel oil input when this was possible.

The unit efficiency determined by the heat-loss method is based on the measured outlet gas temperatures and gas compositions. The outlet conditions were arithmetically averaged. The enthalpy of the flue gases was obtained from standard curves for #6 fuel oil. The gas flows were determined from a fuel oil combustion curve.

Results

A total of 12 tests each were carried out using the fast reaction type and the air atomizing burners. An additional series of three tests was conducted with the fast reaction type burner at substantially the same load, but at varying excess airs. All the tests were conducted while burning a #6

Melvin L. Jones is principal power engineer, Design Division, at Du Pont's Engineering Department. He has been with the company since 1934. Currently, Jones is working on design of power plants and related utilities for chemical plants.

J. H. Born, Jr. is a graduate of Polytechnic Institute of Brooklyn, where he received a B.S.Ch.E. in 1948. Since then, he has been with Foster Wheeler in Service and Staff Engineering work. Born is chief staff engineer, Equipment Division, New York City.

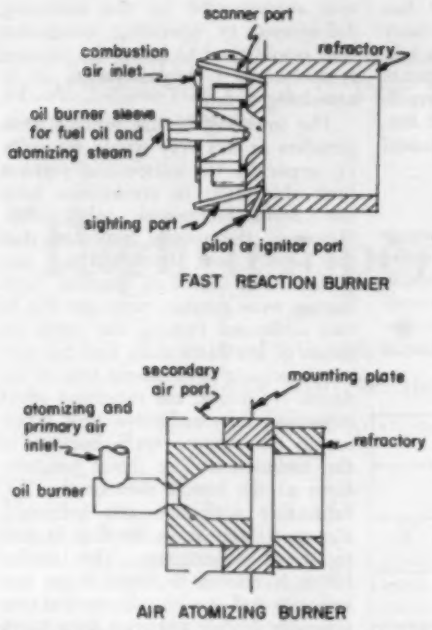


Figure 7. Comparison sections through burners.

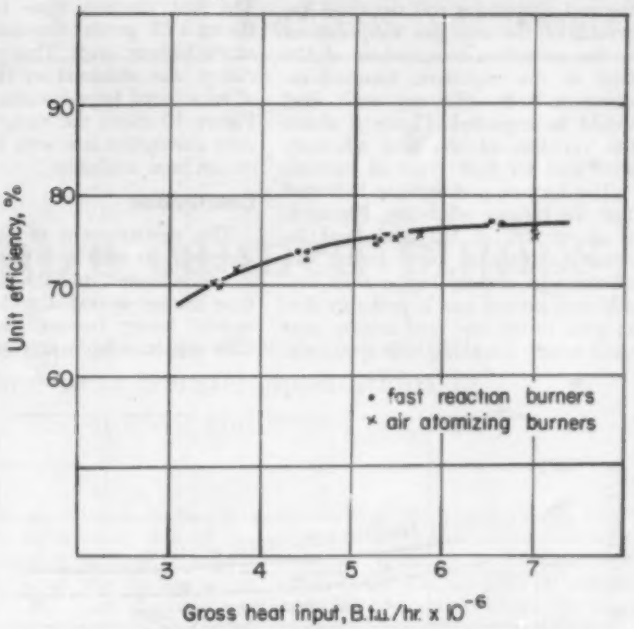


Figure 8. Unit efficiencies at varying heat inputs.

fuel oil. During all tests both burners were in service and the maximum turndown obtainable was limited by the flame stability. The combustion curve, Figure 2, is based on an ultimate analysis of a sample of the fuel oil burned during the tests.

The gas temperatures measured during the tests are plotted as a function of location within the furnace and the operating load on Figure 3. Each point represents an arithmetic average of three temperature measurements taken at the particular load.

The variation of temperature from the front to the rear of the unit follows a pattern very similar to the flame shape. The flame, when firing the air atomizing burner, travels the full depth of the furnace. As it progresses towards the rear wall, it fans out generating a conical surface. The fast reaction burner has a very short visible flame length, of not more than half the furnace depth.

The differences in the shapes of the flames influence the gas temperatures measured in the furnace. The temperatures plotted on Figure 4 illustrate the more uniform and lower temperatures obtained with the fast reaction burner. This is apparently due to enclosure of the combustion reaction zone in a mass of rotating excess air and rapid chemical reaction between the fuel and air in the center core, with complete combustion obtained within half the furnace depth.

The effect of the mass of rotating air surrounding the core exerts its greatest influence as a thermal barrier during the initial phases of combustion. Radiant energy is absorbed by this shield of air, reducing the radiant absorption to the surrounding heating surface to safe limits. By the time the chemical reaction is completed, the gases are transferring the greater portion of the energy by convection rather than radiation.

The air atomizing burner, employs all, or a portion of the theoretically required air, for atomizing purposes with the remaining portion induced as secondary air. In this instance, the chemical reaction requires additional time for completion. The greater part of this time is very likely required for air and fuel particles to intermix. However, since a relatively small portion of the fuel is reacting at any instant, the reaction rate will be slower, due to the fact that the reactants are surrounded by unreactive components that are absorbing energy and lowering the reaction temperature. Thus, the entire furnace is required for the chemical reaction to be completed and the expanding high temperature gases approach close to the heating surface.

The above hypothesis is confirmed by a review of the tube metal temperature shown in Figure 5. Though the furnace gas temperature, measured with the fast reaction burner in use, was considerably lower than with the air atomizing burner, the furnace tube metal temperatures were generally higher. This was apparent in situations where the gas temperatures were as much as 400°F lower, indicating a large amount of radiant energy being transmitted through the relatively cool layer of gas.

The thermocouples located along the "D" tube of the furnace show a definite decrease in metal temperatures in the area of the upper corner bend. This would be expected because this section of the element is further from the flame centerline. The temperatures along the roof section of the element were close to the temperatures measured along the vertical portion of the element. Both of these portions of the element were approximately the same distance from the axial centerline of the flame. These temperature variations are illustrated in Figure 6.

Figure 7 illustrates the principal construction differences between the two burners. Prior to use, the fast reaction type burner was operated on a test stand and the results indicated that a short, rapidly whirling flame could be expected. This was borne out on the actual tests and the flame length did not exceed 4-5 ft. of the ten-foot furnace.

The unit efficiency did not vary significantly from one burner to the other. In both cases the unit efficiency ranged from 70% at low loads to about 78% at high loads. It appears that the principal reason for the similarity of

the unit efficiencies was the close approach of the exit gas temperatures to the saturation temperature of the fluid in the vaporizer. Gradual increase in unit efficiency with load would be expected. Figure 8 shows the variation of the unit efficiency with load for both types of burners.

The furnace performance indicated that the furnace efficiency, Figure 9, is about 65% at full load, and increases slightly at lower loads. This efficiency is slightly higher than usually encountered and is probably due, in part, to the low heat release rates used when designing this type unit.

The fast reaction type burner has shown a 5% greater furnace efficiency at the highest loads. This greater efficiency was obtained at the expense of tube metal temperatures, Figure 5. Figure 10 shows the variation of furnace absorption rate with load, based on net heat available.

Conclusions

The measurement of the furnace temperatures with each type of burner in use indicated that the fast reaction type burner operated with a considerably lower furnace temperature. This reduction in furnace temperature was accompanied by the following differences in operating conditions that would tend to lower the furnace temperature: 1. higher excess air 2. atomizing steam.

The lowering of the furance temperature in this way would normally be expected to reduce the furnace heat absorption in accordance with the Stefan-Boltzmann relationship. However, the results indicated that the furnace heat absorption and efficiency with the fast reaction type burner were greater; probably due to two additional factors: the rapid rotation of the flame mass and the concentrated, highly-luminous core of the flame. No doubt, the rotational effect improved the convective heat transfer to the furnace walls because of the turbulence. The metal temperatures at the lowest part of the "D" tube side wall elements indicated, Figure 6, appear to be due in part to these phenomena. The second factor is related to flame shape and intensity and would indicate that considerably higher radiative heat transfer is being obtained with the fast reaction type burner. This may be due to a clearer furnace and higher reaction temperature at the core of the flame. It is conceivable that the core of this type flame more nearly approaches a condition of stoichiometry or zero-percent excess air, hence the higher reaction temperature.

The higher metal temperatures coincident with the higher heat transfer rates are not without undesirable consequences. In this particular situation, the heat transfer fluid, which is an organic material, will be more prone to thermal decomposition. In this case, the metal temperatures were not excessive and operations were maintained with this burner in service.

In conclusion, the results of this investigation indicate that:

1. The unit efficiency is approximately 75%.
2. The maximum furnace absorption rates approached 10,000 B.t.u./(hr.) (sq. ft.) based upon the total tube surface in the furnace.
3. The fast reaction type burner produced a more uniform gas temperature for the full furnace depth and resulted in somewhat greater furnace efficiency.
4. The fast reaction burner produced higher metal temperatures and can be utilized where high heat release rates are desirable.
5. At lower loads, where the flames from both burners approach similar shapes, the furnace efficiencies approach each other.

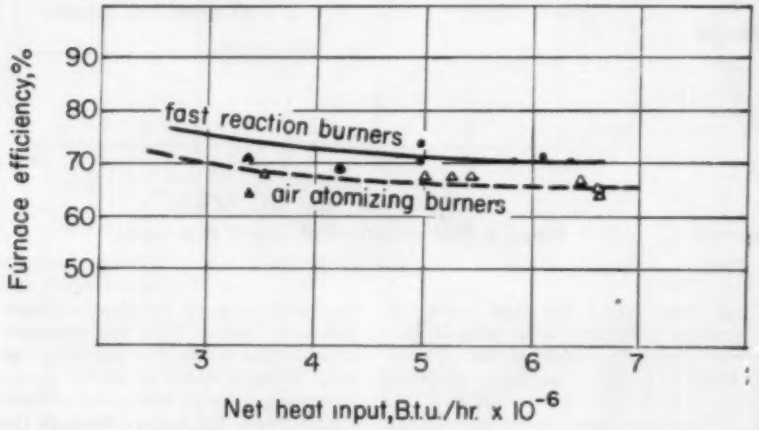


Figure 9. Furnace efficiencies at varying heat inputs.

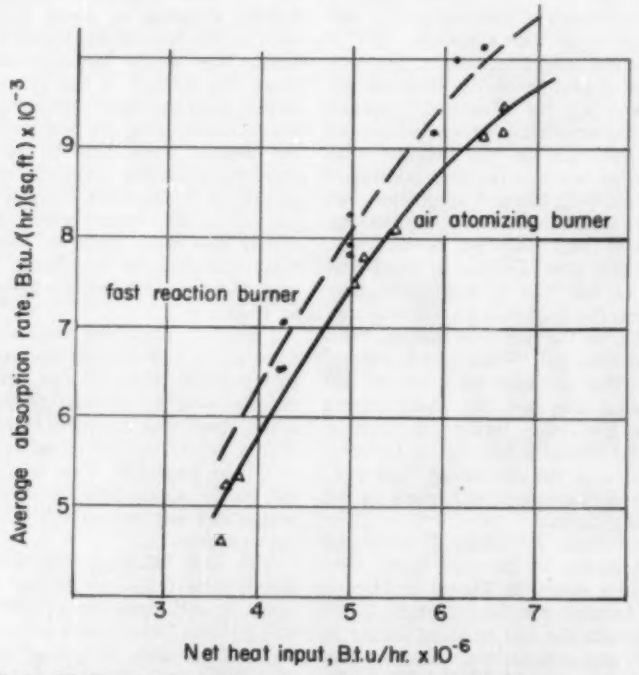


Figure 10. Furnace heat absorption rates at varying loads.

H. A. THORNTON AND A. D. FELL, JR.
Fostoria Corporation

High temperature canned pumps

Canned pumps offer design engineers advantages in high pressure and temperature heat transfer applications in the chemical processing and nuclear industries.

RECENT TECHNOLOGICAL PROGRESS in supplying heat to chemical and industrial processes, heating buildings, and cooling nuclear reactors has led to the wide use of various heat transfer liquids at relatively high temperatures and sometimes high pressures. Increased efficiencies are obtained and smaller systems can be used as a result of the high heat content that is developed in the system. However, in order to obtain best results, the following factors should also be present in the system. The fluid should have: excellent wetting properties, low viscosity, freedom from gas and be noncorrosive to construction materials, and be nonscale forming.

Important system design factors are: turbulent flow, control of uniform heat, sealed system, and safety precautions.

High temperature water systems

Designers of HTW systems recognized that leakage would cause problems in pump location and reduced efficiencies. Pumps having mechanical shaft seals were found to give considerable maintenance trouble, require treated water make-up, increase floor space requirements, and necessitate the use of special safety guards and/or remote location of the pumps. As a result, canned pumps were selected to solve these problems.

An advantage of canned pumps is that it may be located close to operating personnel, electrical equipment, or instrumentation without having the danger of leaks causing burns or shorts. The efficiency of the system can be maintained at a higher level because of the absence of scale, fouling, corrosion, and gas. Leakage causes fine deposits of scale and corrosion, as well as the need for treated water make-up. Oxygen in the system should be avoided due to increased corrosion at high temperatures. Because of this factor, water make-up in any part of the pressurized system or elements should be kept to an absolute minimum.

A suitably engineered HTW system that is pressurized and leakproof requires only a fixed water charge and a fixed gas pressure charge of a neutral, noncorrosive atmosphere. Water treatment may be required, but only at the initial fill. No blowdown is required and interval scale does not build up as in steam systems. Initial start-up boils off oxygen and dissolved gases which are completely vented off prior to pressurization. Efficient heat transfer is maintained throughout the life of the system by the elimination of leakage and the use of a pressurized system.

Some engineering studies have shown that HTW systems are more efficient and less costly in annual

Chempump installation in an atomic test loop at the Nuclear Division of the Martin Co. used to circulate demineralized water at 650°F and 2200 lb./sq. in.

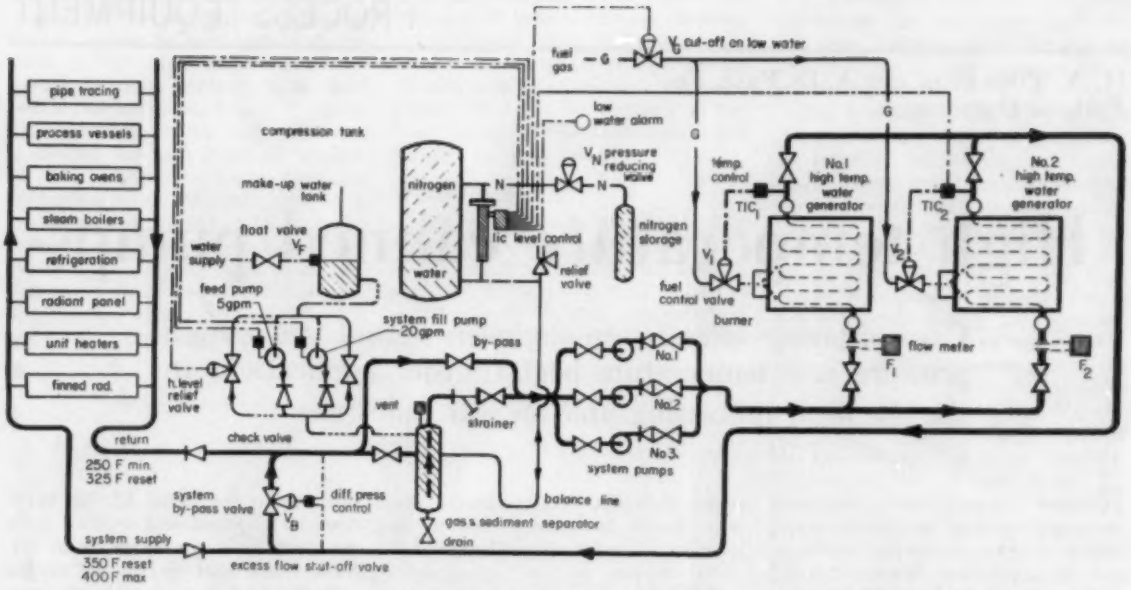


Figure 1. Flow diagram of a typical pressurized high temperature water system showing application of canned pumps.

owning and operating costs than steam systems (*1*). The comparative figures will obviously vary with the system size and pressure. However, HTW systems eliminate or reduce disadvantages of steam systems which include:

1. Condensate return lines, deaerator equipment, blowdown systems, pressure regulating valves, traps, and feed water treatment.

2. Fluctuations in heat load and distribution that reflect themselves back to the boilers causing unsteady firing rates.

3. Scale build-up and corrosion with resultant reductions in heat and fluid flow efficiencies.

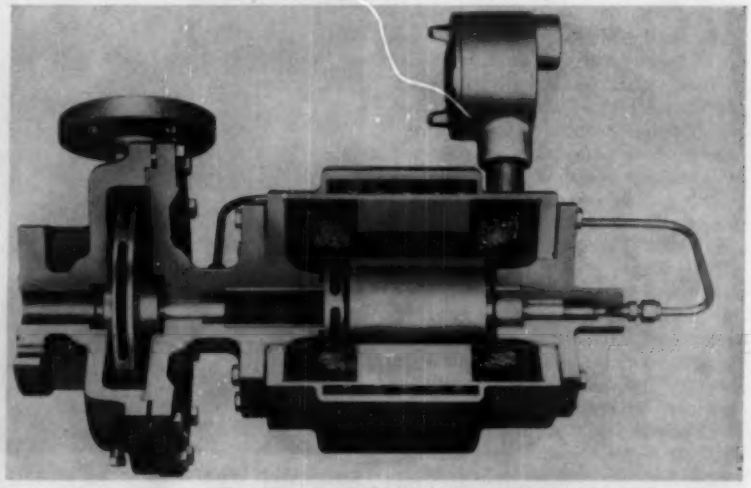
The higher heat content of water at 400 degrees compared with water at 180 degrees requires much less actual piping to supply the same quantity of heat. Smaller pipe and equipment may be used and black iron pipe is suitable. Obviously, in most industrial systems the initial cost is lower. Surveys taken in a number of industrial and government installations have shown savings in operation and maintenance amounting to 16-19% per year.

Closed systems were used in order to minimize fluctuations in system pressures, temperatures, heat content, and corrosion. Pressurization in a closed system is arranged (by way of no leakage) to detect average heating loads and to translate them into controlled, steady firing rates which improve combustion efficiency. Steam will not form regardless of temperature change. Thus, dissolved oxygen, make-up water, water treatment, and corrosion are reduced to a minimum; while heat transfer efficiency is maintained at a high level.

A typical HTW system (*2*) is shown in Figure 1. This is a simplified system which can be increased in size and augmented with auxiliary equipment for industrial processes. HTW systems usually include main system pumps which are located in the return lines to the regenerators. Booster heaters and pumps are used in remote branch circuits to provide a flexible system and take care of various loads. Low pressure steam boilers are used with HTW as the heat source to provide auxiliary steam requirements.

Organic fluid systems

Modern industrial processes use closely controlled heat at high temperatures for a wide variety of operations. Prior to the advent of organic heat transfer fluids, steam and ordinary mineral oils were used. However, the necessarily lower temperatures resulting from the use of these fluids reduced heat contents. For instance, steam at 700°F—an efficient heat transfer temperature—has the disadvantage of a crushing pressure



Cutaway view of series T canned pump for high temperature leak-proof pumping.

of 3000 lb./sq. in. Vessel and jacket wall thickness must be heavy and consequently are expensive.

Todays stable organic heat transfer fluids replace steam and give better efficiency, control, safety, and maintenance costs. Organic heat transfer fluids have low vapor pressures, good stability at high temperatures, and low surface tension with excellent wetting properties. Low surface tension, however, presents the disadvantages of leakage, fluid loss, contamination, and maintenance. These problems are minimized by using a canned pump when handling organic heat transfer fluids.

Typical fluids are Dowtherm (Dow Chemical), Arochlor (Monsanto), and S/V 600 (Socony Mobil). Such fluids as these offer better heat stability, more accurately controlled heat transfer because of more heat content, improved specific heat, and better wetting qualities. For instance, Dowtherm A at 600°F has a saturation pressure of 46 lb./sq. in. abs. compared with 1540 lb./sq. in. abs. for steam. It may be used either in the liquid or vapor phase to transfer heat. With a condensing vapor, all the heat is transferred at the saturation temperature of the vapor and the entire heat surface is maintained at the same temperature.

Since these liquids have excellent wetting properties and low viscosities in the heating range, they are difficult to contain in the usual manner. They are relatively expensive and in some cases escaping vapors may be toxic or have offensive odors. Canned pumps not only eliminate these problems, but also go further and prevent contamination of the fluid, since no oil or grease lubrication is required. Likewise, systems under vacuum do not run the risk of drawing air into the liquid through a leak in the packing gland or seal.

Heat loss is minimized during fluid passage through canned pumps since they are smaller in size than similar conventional units and the fluid flows through faster due to higher pump speeds. Special design modifications are used to minimize connections between pump and motor parts and to allow complete air removal at start-up.

Additional savings are accrued by users of canned pumps for heat transfer fluids through the elimination of a major portion of the installation costs normally encountered with a standard pump motor unit. With a canned pump, in many cases, a base or a concrete pad is definitely not required. In fact, in many heat trans-

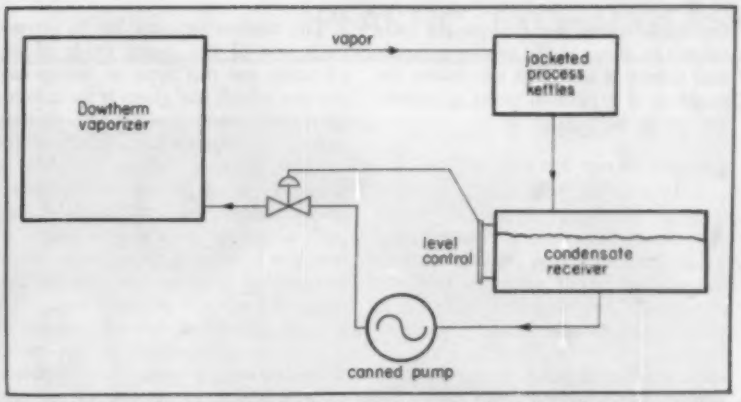
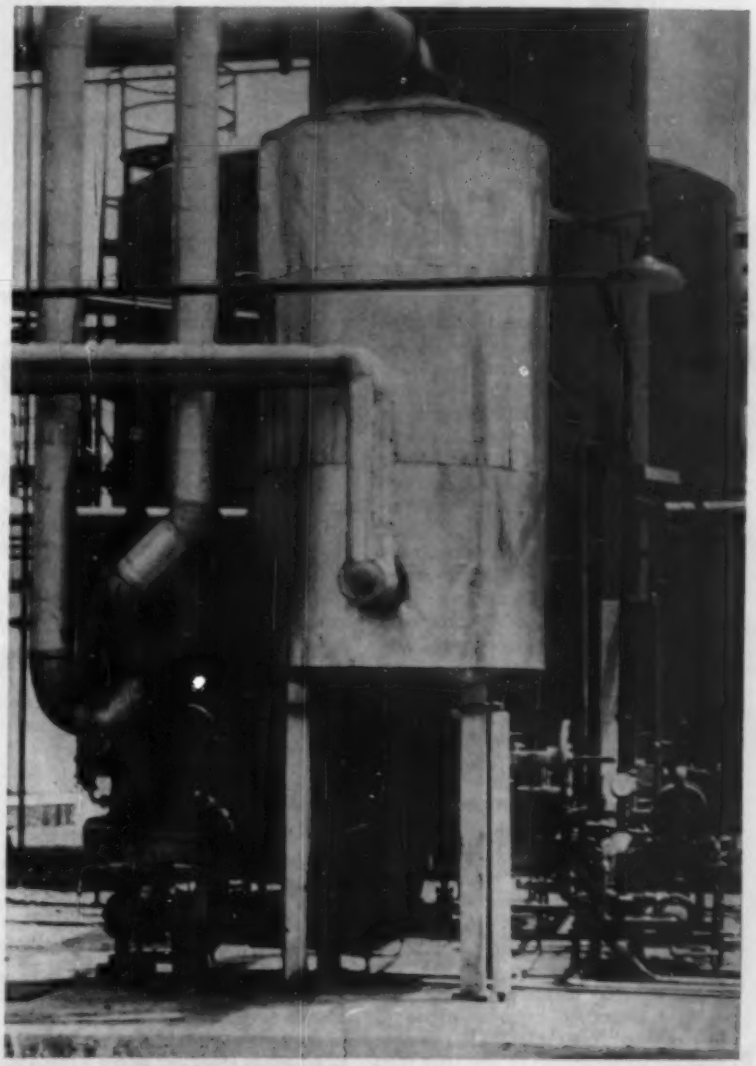


Figure 2. Simplified flow sheet of an organic vapor heat transfer system where canned pump is used for transferring condensate from receiver to vaporizer.



Actual installation of a sealless canned pump mounted under condensate receiver for handling Dowtherm A at 600-700°F used to transfer heat to process equipment.

fer applications the pumps are permitted to move as the piping expands and contracts and thus eliminates the problem of expansion joints to protect the pump castings.

Organic vapor system

A typical example of a vapor system is shown in Figure 2 where the liquid medium is heated and converted to vapor either directly in a boiler or in auxiliary heat exchangers. The vapor then flows to the process vessels (usually jacketed kettles) where the heat is given up and the condensate flows back to the condensate receiver. Here the Chempump usually takes suction from the receiver and returns the condensate to the boiler or reheat exchanger. The pump delivery is normally controlled by a flow or level control system on the receiver to meet the boiler demand.

As to the level changes in the receiver, a valve alternately opens and closes to maintain proper level. In some systems the pump is started and stopped by the level, while in other systems the pump is operated as the high and low limits are reached. On most systems, however, the pump runs continuously and it is possible to operate against a closed discharge valve for an appreciable length of time. To insure maximum operating life, where long periods of operation against shut-off are encountered, a by-pass system should be incorporated. In large systems, where there is a large quantity of condensate, operation at shut-off is rarely encountered.

All of the advantages previously mentioned account for the increasing use of canned pumps in organic heat transfer liquid services. With the continued research, development, and design changes currently being conducted on the canned pump, more and more companies are going to this method of pumping these difficult liquids.

High pressure and temperature

Several process applications of pumps are in services where the temperature range varies from 300 to 800°F and the system pressures range from an almost perfect vacuum up to 5000 lb./sq. in. gauge. In some cases, these extreme variations in pressure and temperature are encountered during a single phase of the over-all operation. The sealing problem encountered in covering such wide situations was one of the major reasons which led to the development of the canned pump.

The nuclear industry has in general been one of the major fields of application for this type of pump and the one which has given it its impetus for rapid development. The maintenance of extremely high purity of the primary loop water has been found desirable in all pressurized water reactors. This is generally accomplished with a by-pass purification system in which a portion of the primary water is removed, purified, and recirculated back to the main primary loop. Here a canned pump eliminates contamination while pumping this high purity water through a mixed-bed demineralizer circuit.

These pumps are also used in heavy water moderated reactors where purity must be maintained to minimize corrosion and retain neutron economy. Purity is again obtained by using a by-pass purification flow through a mixed resin bed.

Due to the cost of heavy water, canned pumps should be used to handle the heavy water product, as well as in process streams where mixtures of light and heavy water are being enriched and/or separated. Heat exchange must be carefully controlled in these applications.

Another application for these pumps is in nuclear powered submarines. Here canned pumps are used on the primary and secondary loop, as well as for decay heat removal purposes. Here again, the requirement of no leakage of this dangerous material and freedom from contamination is a must and again points out the requirement for a canned pump.

Equipment such as valves and heat exchangers which ultimately go into atomic powered installations are developed and tested by means of corrosion test loops. A typical loop used for testing heat exchangers or nuclear valves would encompass a high pressure piping system in which the equipment to be tested would be mounted and a canned pump used to circulate the demineralized water at temperatures in the range of 600°F and pressure of 2500 lb. Such loops enable companies to test and modify equipment so that when the components are used in the ultimate power plant their operation has been predicted successsfully. Here again, the high temperature and pressures encountered in such tests make the canned pump a necessity.

There are many additional areas in the nuclear field where canned pumps have been successfully employed and undoubtedly many more applications will be developed in the future.

The major advantage of elimination of sealing and leakage problems has made the canned pump an intriguing as well as an attractive piece of equipment for the processing industry. Today, it is in its infancy in relation to its ultimate field of application. The next ten years will undoubtedly see a rapid expansion for this type of equipment throughout the processing and nuclear industries.

Fell

Thornton

A. D. Fell, Jr. is sales manager, Chempump Division, Fostoria. A registered professional engineer in Pennsylvania, he has a B.S.Ch.E. from the U. of Penn. Fell formerly held posts with Milton Roy, as chief engineer, and with Chemical Pump and Equipment, as vice president.

H. A. Thornton is with Fostoria's Chempump Division, where since 1952 he has specialized in process application, corrosion, and engineering sales. He has published papers on adsorption and industrial waste treatment.

Pump design tips

Experience in these three types of systems has shown that there are some points to remember, as follows:

1. Express pressure drop data in feet of fluid flowing at the design temperature. Using lb./sq. in. can lead to pitfalls due to lowered specific gravities and viscosities at high temperatures.

2. Avoid the general practice of adding 20% to the design capacity and head. This can lead to excessive pump sizing, costs, and inefficient operation. Impellers should be sized for the normal rating.

3. Install pressure taps or gauges in suction and discharge side of the canned pumps, particularly in welded piping systems. This can save costs in operation and maintenance.

4. Insure that system and pump are vented several times at start-up to remove all gas. Never vent under vacuum conditions.

5. Design systems for the highest practical temperature within limitations of the fluid used and the equipment. This reduces capital and operating costs.

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J. M. WEAVER
*Bechtel Corp.**

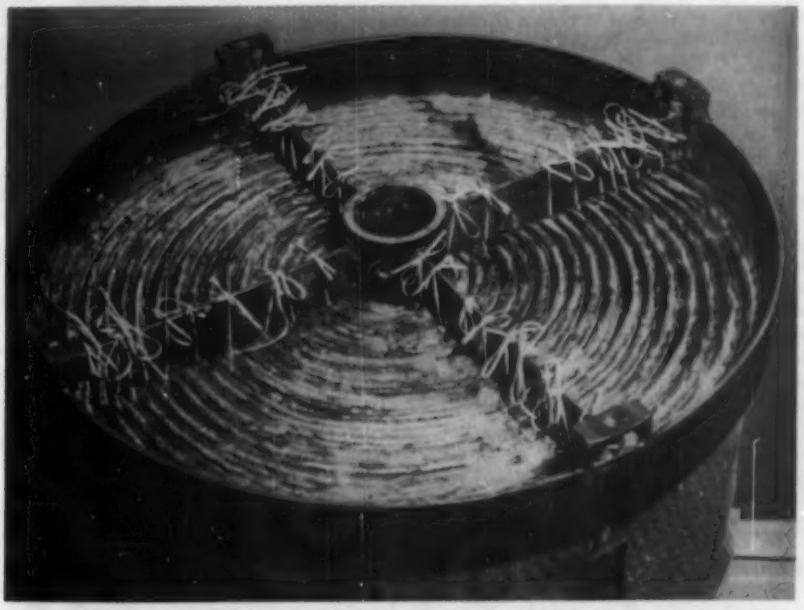

Figure 1. Spirally wound plastic evaporator made to test fabricating techniques.

Plastic film heat exchangers

Substitution of plastics for metals in heat exchangers offers interesting technical and economic potential.

PLASTICS, UNLIKE METALS, do not ordinarily react with dilute acids, bases, or salts. This fact suggests interesting possibilities for their use as heat transfer surfaces since new, tough plastic films with improved properties are being developed each year. Their costs are only cents/sq. ft. compared to dollars/sq. ft. for metals. The conductivity of plastics is much less than that for metals, but the lower cost and thin wall potentials of plastics more than compensate for the lower conductivity.

Plastic film, like all materials, has certain physical and chemical limitations. Probably the most important limitation of plastic film for use in heat exchangers is its inability to resist a continuous pressure normal to its surface under certain combinations of pressure and temperature without permanently distorting the film. Therefore, a successful plastic film heat exchanger must have very little or no pressure differential normal to the surface. When a slight pressure across the film is necessary to the design of the heat exchanger, then the film must be supported at very short intervals.

Costs of exchanger materials

If a given amount of heat is transferred in a given time through a given ΔT, the comparative costs of two different materials such as plastic and metal are given by the formula

$$\frac{C_m}{C_p} = \frac{c_m k_p x_m}{c_p k_m x_p}$$

where terms are defined in the Notation. A derivation of this equation is shown in this article.

The unit values for 0.002-in. polyester film and 0.5-in. Monel tubing (least expensive Monel tubing per sq. ft.) are as follows:

MONEL		POLYESTER	
c_m	$6.80	c_p	$.02
k_m	15.0	k_p	.088
x_m	.008	x_p	.002

Substituting these values in the above equation gives

$$\frac{C_m}{C_p} = 7.9$$

The cost of Monel tubing is about eight times as much as the cost of the polyester film for heat transfer surfaces of the same capacity. Since the condensing film and the liquid film coefficients, and not thermal conductivity, are generally the controlling factors to heat flow, the comparison becomes even more favorable for plastic film.

Plastic film cannot be used efficiently with high heat flux densities. Therefore, with relatively low heat flux densities it is necessary to compact a large heat transfer surface into a unit of volume to obtain high heat transfer capacity per unit volume.

* *Weaver was with National Aluminate when this work was performed.*

Assume the use of a 0.002-in. thick polyester film as the heat transfer surface. With a beat flux density of 500 Btu./(sq. ft.)(hr.) the temperature drop through the film will be 0.95 °F. If this film is spaced 0.2 in. apart in a plastic film heat exchanger there will be 60 sq. ft. of film per cu. ft. of volume. Since 500 Btu will evaporate one-half pound of water, the evaporator will have a capacity of 30 lb./(hr.)(cu. ft.) with a temperature drop through the film of less than 1°F. This capacity compares favorably with that of metal evaporators.

Plastic heat exchangers

A number of different types and designs of heat exchangers are possible using plastic film. One such design has been described, built, and tested by Maria Telkes for the Office of Saline Water (*1*). The Telkes multi-effect still consists of ten parallel vertical polyester films mounted on frames and spaced one-half in. apart on both sides of a central heat source. The liquid to be evaporated is distributed across the outer top surface of each film by means of a porous fabric cemented to the outer surface of the film. The sum of the water vapor pressure and the air pressure in each effect equals atmospheric pressure.

Heat flows from the central heat source successively through each effect. Water evaporates from the porous fabric, diffuses through the air space and condenses on an adjacent condensing surface where it runs down into a trough and is collected.

Telkes reports that after several weeks of continuous operation using sea water, the evaporator layers "... were entirely free of salt deposits" and that "There was no difference in the appearance of the flannel on the first stage operated at the highest temperature (maximum 200°F) and the last stage." The distillate to concentrate ratio was as high as 1.38.

Evaporation occurs from the surface of the porous evaporator layers without boiling. This, combined with the low heat flux density appears to be the reason why no deposits were formed.

The chief limitation of this design is its low capacity. The outer effects which have a high air to vapor ratio act as a bottleneck to heat transfer for the whole still.

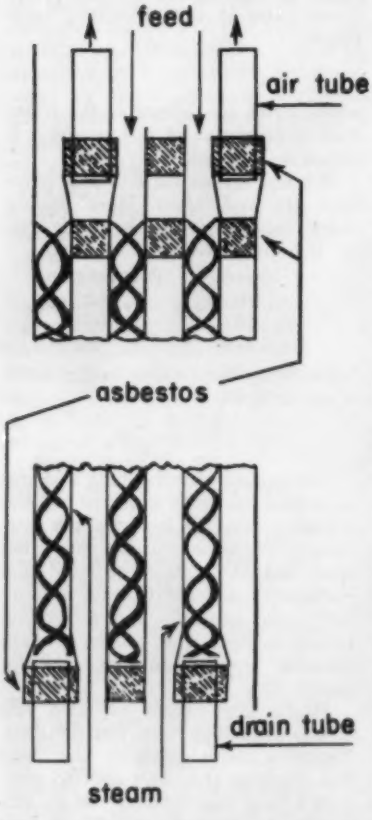

Figure 2. Falling film evaporator fabricated from plastic materials.

Spirally wrapped evaporator

A more efficient form of this diffusion type multi-effect evaporator would be one consisting of plastic film spirally wrapped around the heat source with at least one vertical partition per wrap to inhibit convection currents between the different effects (Figure 1). In this design the outer effects have progressively larger surfaces to help compensate for their progressively lower heat transfer coefficients. Also, there is no problem of heat and vapor leakage at the vertical edges as there is in the flat frame still.

The spirally wrapped evaporator could be fitted compactly into a steel cylinder and could be operated at pressures other than atmospheric. If this evaporator is operated with 145°F in the first effect and 70°F in the last effect, the still could be operated at approximately three lb. absolute pressure. This would remove most of the air from the outer effects and would greatly improve the over-all heat transfer. An estimate of this improvement in heat transfer in the space between the evaporating surface and the condensing surface of the outer effect can be shown by the following analysis.

The diffusivity of one gas in another varies inversely with the absolute pressure (*2*). Diffusivity in the case of water vapor should be proportional to the heat transfer coefficient U because a definite quantity of water vapor transferred represents a definite quantity of heat transferred. Therefore,

$$\frac{D_3}{D_{14.7}} = \frac{U_3}{U_{14.7}} = \frac{14.7}{3} = 4.9$$

A factor of 4.9 is a very worthwhile improvement in heat transfer coefficient.

Circulating air-vapor evaporator

Another type of non-boiling evaporator that could effectively utilize the properties of plastic film would be a circulating air-vapor evaporator, one end of which would be hot and the other end cold. It could be operated at any pressure in a closed vessel. The plastic film could be fabricated and suspended as long, flat tubes, the axes of which are horizontal. The outside of the tubes would be wetted with a flowing film of liquid to be evaporated. The in-

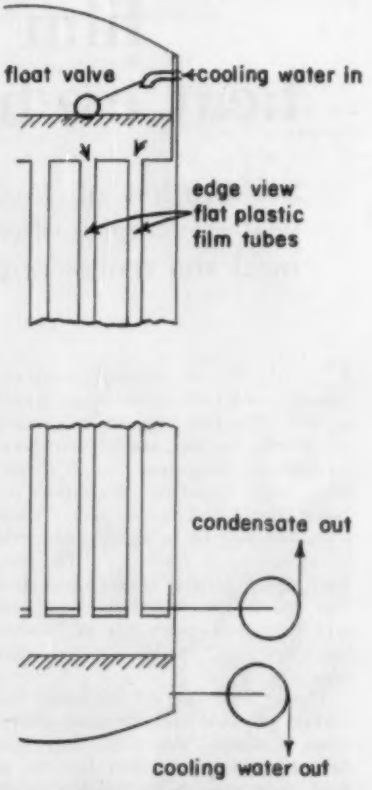

Figure 3. Section of surface condenser showing where plastics might be used.

side of the tubes would be a condensing surface.

The saturated vapor moves inside the tubes from the hot end to the cold end condensing as it goes. At the cold end it is cooled an additional few degrees by a surface condenser. The cold saturated air returns on the outside of the tubes to the hot end of the evaporator and is heated on the way by contact with the evaporating liquid. There is counter current heat exchange between the condensing vapor and the evaporating liquid.

The heat added at the hot end and withdrawn from the cold end maintains the condensing surface at a slightly higher temperature than the evaporating surface. This causes the heat of condensation to flow through the wall of the heat transfer surface and to evaporate the liquid on the evaporator side of the surface, thereby achieving a multi-effect use of heat.

The outside surface of the plastic tubes could be coated with asbestos fines causing the liquid to distribute itself uniformly. The efficiency of this evaporator would depend on the circulating rate of the vapor, but by assuming a modest ΔT across the surfaces, one pound of steam should evaporate many pounds of water.

A spacer such as crimped Monel mesh would have to be used either between the tubes or inside the tubes depending upon the location of the circulating fan. Crimped Monel wire mesh (0.009 in.) would increase the cost of the heat transfer surface about $0.17/sq. ft. This cost is still much less than a sq. ft. of alloy tubing.

John M. Weaver is with Bechtel Corp. in San Francisco. Before joining Bechtel he was plant engineer for Nalco Chemical's Catalyst Division in Chicago. Weaver has also been associated with Bowen Engineering, where he was test engineer for the spray dryer manufacturing firm, and with Armstrong Cork. He has a degree in Physics from MIT.

Advantages to be expected from this evaporator are (1) a multi-effect use of heat within one shell, (2) high heat transfer rate per unit of volume, (3) evaporation without boiling to eliminate or minimize scaling.

Falling film evaporator

An experimental falling film evaporator as shown in Figure 2 was built with 200 sq. ft. of surface area best described as a spiral channel with a crimped wire mesh spacer to hold apart the sides of the channel. The bottom of the channel is sealed with 3/16 in. square braided asbestos and synthetic rubber. The channel is drained by plastic tubing outlets. The evaporator is made from one continuous piece of polyester film. The feed is distributed over the inside of the channel surface by means of the crimped wire mesh and a coating of asbestos fibers. The film is spaced 0.2 in. apart so that a cu. ft. of evaporator has 60 sq. ft. of surface. The evaporator is mounted in a light steel frame.

Potential plastic applications

It would seem possible to build a successful liquid-liquid heat exchanger in the form of horizontal tubes or channels with flattened vertical surfaces provided velocities were low and spacers were used in the passages of the lower density liquid. Overflows could be installed in the ends of the heat exchanger so that both liquids could be maintained at the same levels.

Plastic film might also be used in a surface condenser as shown in Figure 3. Water would fall through a flat tube of plastic film at any desired velocity. The velocity depends upon the width of the slotted orifice at the top. A film of water falling at a rate of 3 ft./sec. is about 3/32 in. thick. The film thickness is uniform apparently because the work of friction exactly balances the work done by gravity in each section.

Derivation of Relative Cost Formula

The relative cost for metal and plastic heat transfer surfaces is given by the equation:

$$\frac{C_m}{C_p} = \frac{c_m A_m}{c_p A_p} \quad (1)$$

For heat transfer surfaces of the same capacity,

$$\frac{q}{\Delta T} = \frac{k_m A_m}{x_m} = \frac{k_p A_p}{x_p} \quad (2)$$

from which

$$\frac{A_m}{A_p} = \frac{k_p x_m}{k_m x_p} \quad (3)$$

Substituting (3) into (1) obtain the relative cost formula

$$\frac{C_m}{C_p} = \frac{c_m k_p x_m}{c_p k_m x_p}$$

NOTATION

- A_m = area of metal heat exchanger
- A_p = area of plastic heat exchanger
- C_m = cost of metal heat exchanger
- C_p = cost of plastic heat exchanger
- c_m = cost of metal heat exchanger per unit of area
- c_p = cost of plastic heat exchanger per unit of area
- D_3 = diffusivity at 3 pounds pressure, sq.ft./hr.
- $D_{14.7}$ = diffusivity at atmospheric pressure, sq.ft./hr.
- k_m = metal thermal conductivity, B.t.u./(hr.)(sq.ft.)(°F/ft.)
- k_p = plastic thermal conductivity, B.t.u./(hr.)(sq.ft.)(°F/ft.)
- q = rate of heat flow, B.t.u./hr.
- ΔT = finite temperature difference
- U_3 = heat transfer coefficient between evaporating and condensing surfaces at 3 lb. abs. press., B.t.u./(hr.)(sq.ft.)(°F)
- $U_{14.7}$ = heat transfer coefficient between evaporating and condensing surfaces at atmospheric pressure, B.t.u./(hr.)(sq.ft.)(°F)
- x_m = thickness of metal surface
- x_p = thickness of plastic surface

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HERBERT T. BATES, *Kansas State University*

Economical drying of solids

The practical approach to drying problems. How to figure drying times and drier sizes for rapid drying of solid particles.

DRYING IS EXPENSIVE COMPARED to other unit operations. However, when drying cannot be avoided it is desirable to dry the material as rapidly and as economically as possible. Because heat for drying solids must be transferred through an air film to the solid and because upon evaporation the vapor must also be transferred across an air film, drying, at best, is slow. Most of the costs associated with the drying of solids can be attributed to the low transfer rates across the air film and in the interior of the solid. If water can be removed from solids by any mechanical means it is preferable to do so to reduce the over-all cost.

Some drying problems require special treatment. But, on the other hand, a large number of materials require no special treatment. This article will be restricted to methods of drying the last-named materials. For convenience, it is desirable to consider driers primarily as heat exchangers.

Constant drying conditions

When a sufficiently wet solid object is placed in a current of hot air, moisture evaporates from its surface and is transferred as a vapor through the air film that covers its surface. The heat necessary for the evaporation must come from the air current, after an initial period during which the drying solid reaches an equilibrium temperature. Heat is transferred through the surface air film to the wet surface.

As long as the solid remains wet on the surface its equilibrium temperature is identical with the wet bulb temperature, if the heat transfer area and the mass transfer area are the same. It is undesirable to dry solid particles in a solid bottom tray, because this reduces the rate of vaporization unnecessarily.

During the time the surface remains wet, the drying rate remains constant; and this rate can be predicted, although not accurately, from empirical equations (*1, 2*). Rate coefficients from these two sources differ by a factor of 7, indicating differences in the air flow pattern over the surfaces of the solids and also the uncertainty in the actual surface area under test. Rate equation for the constant-rate period may be written

$$R_c = -\frac{dW}{Ad\Theta} = \frac{h(T - t_w)}{r} \qquad (1)$$

This equation may be used with experimental data taken under constant-drying conditions to obtain an accurate value of the convection coefficient of heat transfer h consistent with the value of area A being used. The proper value of A to be used is frequently uncertain, but the product hA should be correct if based on an experimental test.

Material supplementary to this article has been deposited as Document No. 6309 with A. D. I. Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington 25, D. C. Photoprints or microfilm obtainable by remitting $1.25 in advance, or checks or money orders payable to: Chief, Photoduplication Service, Library of Congress.

The mass velocity of air past the solid should be the same as that to be employed in the commercial drier; otherwise, it will be necessary to extrapolate the convection coefficient according to some power function. This in turn requires the air flow pattern to conform to some recognizable pattern for which the power function is known. McCabe and Smith (*2*) suggest that this varies between the 0.37 and 0.80 power.

When the object has dried sufficiently, the capillary structure of the solid can no longer bring water to the surface in quantity sufficient to keep the surface completely wet. One or more of several phenomena may develop at this point (*3*).

Coarse capillaries. If the capillary structure is uniformly coarse, as in a bed of coarse sand, capillary forces are weak; gravity draws water downward and permits the top surface of the bed to dry sooner than the bottom surface. Clearly, it is more important to dry from the bottom than from the top in this case. Furthermore, as will be shown later, stirring the bed and exposing individual particles to the drying air is important if the drying rate is to be kept high until the material is nearly dry.

Individual particles of silica sand have no significant capillary structure; so, if individual particles can be dried out-of-contact with one another, the rate will remain constant almost to the end of the process (*4*). It is important to take advantage of this fact.

Nonuniform capillaries. If the capillary structure is nonuniform, the small capillaries suck the coarse ones dry. In this case the drying rate appears to decrease, but actually the moist surface area steadily decreases. This situation has been called the *funicular* state (*3*). It can usually be avoided. For example, it occurs if coarse particles having a fine porous structure are piled together; but the drying rate can be kept at a high constant rate level much longer if the individual particles are dried free of contact with one another. If the funicular state persists for a considerable time, the drying rate-free moisture curve of the material will exhibit breaks at two places.

Salts in capillaries. If the moisture in the drying object contains dissolved salts, evaporation at the capillary openings may cause a deposit of crystals at these points, further reducing the capillary openings. The capillary forces then become quite intense. If the solid structure does not fail, the continued evaporation eventually leads to a condition where the liquid snaps back a distance into the interior and then retreats steadily toward the center of the solid. In this case, there will be a very sharp drop in rate at the critical free-moisture point.

In many instances the capillary structure is small enough, or the structural characteristics of the solid are so weak, that structural failure occurs. For example, when grapes are dried they shrivel to the wrinkled forms we call raisins.

Colloidal capillaries. Colloidal materials possess extremely fine capillary structures so that the capillary force developed in drying is particularly intense. Furthermore, the moisture is held tightly to the solid by forces more nearly chemical in character than physical. When the falling rate period is reached, the moisture concentration gradient in the interior of a colloidal solid varies gradually instead of sharply. If, however, the solid exists as very thin flakes, the falling rate period becomes less important, and the following rate equations are not seriously in error.

Nonhygroscopic materials. Nonhygroscopic material behaves differently from colloidal. When the falling rate period is reached, there is a moist central zone having almost uniformly high moisture concentration and a dry zone near the surface having almost uniformly low moisture content. There is a plane of vaporization between these zones where moisture concentration rises steeply from one level to the other. Since it is practically impossible to dry colloidal materials rapidly, consideration will be restricted to less hygroscopic materials.

Dry surface. When the entire surface of a drying solid object goes dry, the liquid content is held in a central zone beneath the surface by capillary forces. This condition is called the *pendular* state (5). The resistance to heat and vapor transfer is increased to include the dry portion of the solid as well as the air film. Consequently, the drying rate decreases. The rate equation must be modified to include the additional resistance.

$$-\frac{dW}{Ad\Theta} = \frac{(T - t_w)}{r\left(\frac{1}{h} + \frac{LA}{kA_{av}}\right)} \qquad (2)$$

To simplify the analysis Equation 2 assumes that the wet part of the solid interior remains at the wet bulb temperature. Measurements with buried thermocouples indicate that this in-

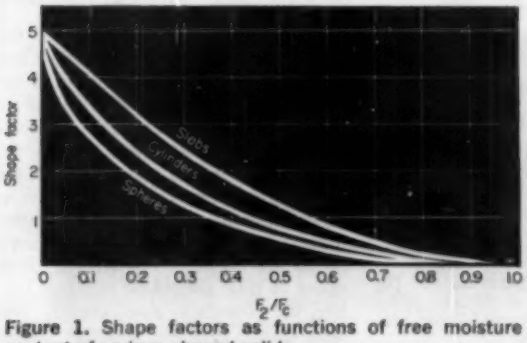

Figure 1. Shape factors as functions of free moisture content of various shaped solids.

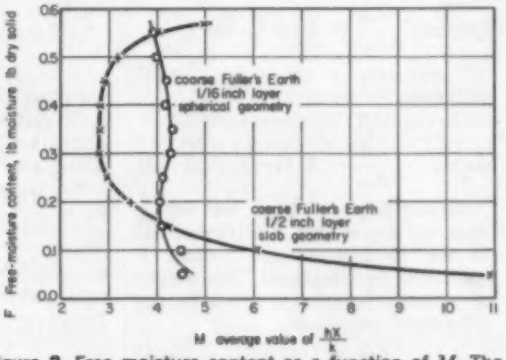

Figure 2. Free moisture content as a function of M. The M factor can increase to infinity as F approaches zero.

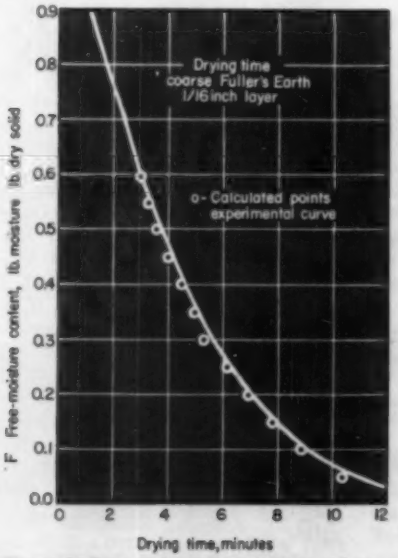

Figure 3. Free moisture content as a function of drying time. If an average value of M is used in the time of drying equations, the results are reasonably satisfactory.

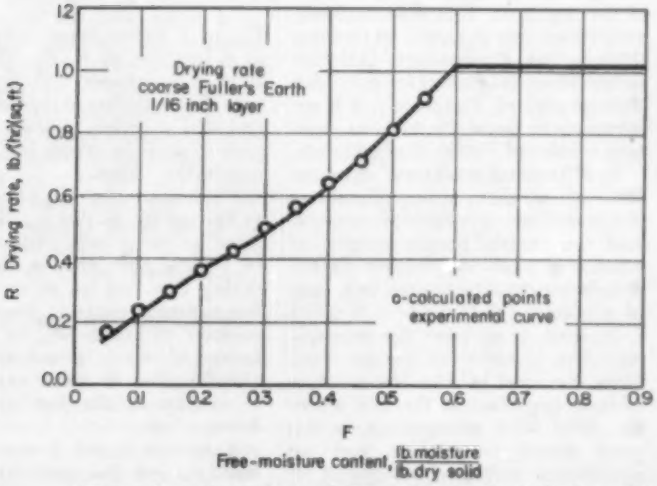

Figure 4. Drying rate vs. free moisture content. Drying rates are more sensitive to experimental errors than drying times.

terior zone does actually rise slightly above the wet bulb temperature; but in several solid objects tested, this rise was slight (3, 6).

Before Equation 2 can be integrated it is necessary to express the distance L and the average area A_{av} in terms of the free-moisture content of the material (7). This depends upon the shape of the solid particles. In the case of spheres of radius X having a wet zone of radius x the free-moisture content is proportional to the cube of x, assuming that moisture content is uniform. It is also known from heat transfer theory that the geometric mean area should be used for spheres. For long cylinders of radius X with a wet zone of radius x, the logarithmic mean area is used. And for slabs whose half-thickness is X with a wet zone whose half-thickness is x, there is no need to average the area. Hence the expression LA/A_{av} becomes:

$$\text{spheres;}\quad \frac{LA}{A_{av}} = X(\sqrt[3]{F_e/F}-1)$$

$$\text{cylinders;}\quad \frac{LA}{A_{av}} = X \ln \sqrt{F_e/F}$$

$$\text{slabs;}\quad \frac{LA}{A_{av}} = X\,(1-F/F_e) \qquad (3)$$

To develop equations for drying time, the dry weight of solid material D and its free-moisture content F must now be introduced. The weight of moisture removed is given by the differential equation

$$dW = DdF \qquad (4)$$

Before this can be integrated, the datum level of equilibrium moisture content must be established. It is well known that the absolute equilibrium moisture content of solids varies with the temperature and humidity of the drying air (8). No completely satisfactory way is known to combine these factors. Furthermore, hysteresis occurs when some solids are dried and then rehydrated. Fortunately, it is not necessary to know the residual moisture content of a solid at equilibrium.

In a "constant conditions" drier the level of moisture at equilibrium is designated zero free-moisture content. And the various sample weights at successive times are related to the sample weight after a very long time of exposure.

In continuous driers the temperature and humidity of the air vary. Since the level of zero free-moisture is most important at the end where the dried solid emerges, air at this point should be used to find the equilibrium weights of samples of input and output solids. Alternately, the air temperature and humidity should be duplicated in the drier used to dry input and output samples to equilibrium. Failure to do so has sometimes led to the erroneous conclusion that the commercial drier has produced solids with a negative free-moisture content.

In the case of hygroscopic solids it is important that experimental tests and commercial runs be based on the same datum level of free-moisture content. Otherwise, there could be a shift in the level of the critical free-moisture content too large to ignore. If the datum level of free-moisture content of a particular solid is not changed, the critical free-moisture content is fixed by the capillary structure and it is not affected by changes in the drying air temperature, humidity, or velocity.

Constant rate drying time. Equations 1 and 4 are combined and integrated to find the constant rate drying time.

$$\Theta_c = \frac{rD(F_1 - F_c)}{hA(T - t_w)} \qquad (5)$$

Falling rate drying time. Equations 2, 3, and 4 are combined and integrated to get an expression for the falling rate drying time.

$$\Theta_f = \frac{rD(F_c - F_2)}{hA(T - t_w)} + \frac{rD(hX/k)F_c}{hA(T - t_w)}[\text{shape factor}] \qquad (6)$$

where the shape factors are:

$$\text{slabs;}\quad [1 - F_2/F_c] - 1/2[1 - (F_2/F_c)^2]$$

$$\text{cylinders;}\quad 1/2[1 - F_2/F_c] + (F_2/F_c)\ln\sqrt{F_2/F_c}$$

$$\text{spheres;}\quad 3/2[1 - (F_2/F_c)^{2/3}] - [1 - F_2/F_c] \qquad (7)$$

Figure 1 shows these shape factors as a function of F_2/F_c. The curves show that spheres will dry in less time than cylinders of the same radius, and that cylinders will dry more rapidly than slabs whose half-thickness equals the radius.

Consideration of Equation 6 leads to the conclusion that a solid may be dried to zero free-moisture content in a finite time; that is, the rate of drying does not go to zero at zero free-moisture content. Since this is contrary to experience, an empirical factor M may be substituted for (hX/k). The M factor can increase to infinity as the free moisture F becomes zero.

Equations 5 and 6 may be combined to get the total drying time. Drying time is the sum of two terms: the time necessary for the desired reduction in free-moisture content at the constant drying rate; and the additional time needed because the drying rate decreases. The second term must be added below the critical free-moisture content.

Evaluating the constants

If the solid particles are of irregular shape and size, the proper average value of X is uncertain. Since the thermal conductivity of the dry portion of the solid may also be unknown, the following experimental method is needed to investigate these factors. Divide Equation 1 by 2, and solve for $hX/k=M$:

$$\text{slabs;}\quad M = \frac{(R_c/R) - 1}{1 - (F/F_c)}$$

$$\text{cylinders;}\quad M = \frac{(R_c/R) - 1}{1/2 \ln (F_c/F)}$$

$$\text{spheres;}\quad M = \frac{(R_c/R) - 1}{\sqrt[3]{F_c/F} - 1} \qquad (8)$$

If a drying test is run under the desired conditions of temperature and humidity and if weight-time data are taken with great care at frequent intervals, the drying rate-free moisture curve can be calculated. Since the drying rate is the derivative of the raw data, it may be necessary to smooth the data by the use of a finite-difference table. If the weight increments are uniform, the second differences of time should be constant during the constant rate period; and they should increase smoothly during the falling-rate period.

Noting the value of the constant rate and employing Equation 1, the value of the surface coefficient of heat transfer h may be calculated. The value of area A used in this calculation may be an arbitrary one; the product hA, however, will be experimentally correct.

For each point on the falling-rate curve the value of the dimensionless group M may be determined from Equations 8. It is best to find M at a number of different values of F, and it is usually wise to try it for slabs, cylinders, and spheres because the solids may be of various odd shapes and sizes and because of the unjustified assumption that the wet interior zone remains at the wet bulb temperature. In some cases there may also be a zone in which the funicular state exists. These are probably the principal reasons that M varies.

Usually one of the geometries will yield a more nearly constant value of M than the others. If this is so, that geometry should be adopted for the remaining calculations. Usually

Notation

A = area of solid, sq. ft.
D = mass of dry solid in equilibrium with drying air, lb. for constant drying conditions; lb./hr. for continuous driers
F = free moisture content, lb. moisture/lb. dry solid
G = mass rate of dry air, lb./hr.
H = humidity of air, lb. moisture/lb. dry air
h = total coefficient of heat transfer across air film, B.t.u./(hr.) (sq. ft.) (°F)
k = heat transfer conductance of dry solid, B.t.u./(hr.) (ft.) (°F)
L = length of path through dry portion of solid, ft.
M = average value of hX/k
m = defined by Equations 18 and 20
n = defined by Equations 30 and 32
p = defined by Equations 14 and 16
R = drying rate, lb./(hr.) (sq. ft.)
r = latent heat of vaporization of moisture at wet bulb temperature, B.t.u./lb.
s = humid heat of air, B.t.u./(°F) (lb. dry air)
T = dry bulb temperature of air, °F
t = temperature of solid, °F
W = weight of moisture, lb.
X = radius of spheres or cylinders or half-thickness of slabs, ft.
x = radius of moist interior zone of spheres or cylinders or half-thickness of slabs, ft.
y = defined by Equations 27 and 35
z = $\sqrt[3]{F/F_c}$
Θ = time, hr.

subscripts

1 = inlet conditions
2 = outlet conditions
C = surface drying zone
c = constant rate or critical free moisture
F = zone of interior drying
p = constant pressure heat capacity
s = solid surface
w = wet bulb temperature of water

M is reasonably constant until F approaches zero. Then it rises rapidly to infinity. Ordinarily it is not advisable to dry solids to *very small* free-moisture contents; thus the rapidly rising portion of the F vs. M curve may be neglected, Figure 2. When coarse Fuller's earth was dried in a thin layer, as recommended above, M varied less than 20%. When a deeper layer was dried, M varied by a factor of 2. In the majority of cases, if an average value of M is used for hX/k in the time of drying equations, the results will be reasonably satisfactory, Figure 3. If an average value of M is used to predict the instantaneous rate of drying, significant differences are noted between the calculated and experimental results, Figure 4, because drying rates are much more sensitive to experimental errors than are drying times.

Herbert T. Bates is Associate Professor of Chemical Engineering, Kansas State U. He has also taught at Case Institute and the U. of Nebraska. A graduate of Iowa State, where he received a B.S.Ch.E. and Ph.D., Bates has an M.S. from Virginia Polytechnic Institute. A patent holder, he is author of several technical papers. Bates, a member of A.I.Ch.E., also holds memberships in ACS, ASEE, NSPE, Sigma Xi, and other societies.

Counterflow adiabatic driers

In large commercial driers it is not economical to operate under constant drying conditions. Consequently, the solid and the drying air pass continuously through the drier, which is insulated and, therefore, the operation is nearly adiabatic. The most efficient arrangement is to operate countercurrently so that the driest solid will be contacted by the driest air, Figure 5. It is assumed that the critical free-moisture content of the solid is independent of the conditions of the drying air. D must be redefined as the dry solid flow rate in lb./hr. and the dry air rate G, lb./hr. is introduced.

Surface drying zone; any shape

If an increment of drier length is chosen in the zone of surface drying and the differential equations for a water material balance, a heat balance, and a heat transfer rate are prepared and integrated over the left section of the drier, Figure 5, the following equation results:

$$\frac{hA_C}{Gs} = \ln\left(\frac{T_c - t_w}{T_2 - t_w}\right) \qquad (9)$$

This is written in dimensionless form for simplicity.

Two of the heat balances are useful in evaluating Equation 9:

$$Gs(T_c - T_2) = rD(F_1 - F_c)$$
$$Gs(T_1 - T_2) = rD(F_1 - F_2) \qquad (10)$$

Interior drying zone

Slabs. To the right of the boundary, the resistance to heat transfer must include the dry portion of the solid from the surface to the zone of vaporization as well as the gas film. Such an equation is:

$$-rDdF = \frac{(T - t_w)dA}{\frac{1}{h} + \frac{LA}{kA_{av}}} \qquad (11)$$

To express T in terms of F, a heat balance around the left end may be written.

$$T = T_2 + \frac{rD}{Gs}(F_1 - F) \qquad (12)$$

The appropriate substitution for LA/A_{av} is obtained from Equation 3 and the integration performed for the right end of the drier. The result is:

$$\frac{hA_F}{Gs} = M\left(\frac{F_c - F_2}{F_c}\right) + [1 + M(1 + p^2)] \ln\left(\frac{T_1 - t_w}{T_c - t_w}\right) \qquad (13)$$

where M is given by Equations 8 and

$$1 + p^2 = -\frac{Gs(T_c - t_w)}{rDF_c} \qquad (14)$$

In some cases drying might be carried out without any zone of surface drying if $F_1 < F_c$. Then $A_C = 0$ and

$$\frac{hA}{Gs} = M\left(\frac{F_1 - F_2}{F_c}\right) + [1 + M(1 + p^2)] \ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right) \qquad (15)$$

where

$$p^2 = -\frac{Gs(T_2 - t_w) + rDF_1}{rDF_c} \qquad (16)$$

Cylinders. Proceeding in the same way for long cylindrical solid particles it is found that

$$\frac{hA_F}{Gs} = \ln\left(\frac{T_1 - t_w}{T_c - t_w}\right) - \frac{M}{2}\left[\ln\left(\frac{F_2}{F_c}\right) \ln(1 - m_2) - (m_c - m_2) - \frac{m_c^3 - m_2^3}{2^3} - \frac{m_c^5 - m_2^5}{3^2} - \text{etc.}\right] \qquad (17)$$

where

$$m_2 = \frac{rDF_2}{Gs(T_2 - t_w) + rDF_1} \text{ and}$$

$$m_e = \frac{rDF_e}{Gs(T_2 - t_w) + rDF_1} \quad (18)$$

If there is no zone of surface drying and $F_1 < F_e$ then $A_C = 0$ and

$$\frac{hA}{Gs} = \ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right) - \frac{M}{2}\Big[\ln\left(\frac{F_2}{F_e}\right)$$

$$\ln(1 - m_2) - \ln\left(\frac{F_1}{F_e}\right)\ln(1 - m_1)$$

$$-(m_1 - m_2) - \frac{m_1^2 - m_2^2}{2^2} - \text{etc.}\Big] \quad (19)$$

where

$$m_1 = \frac{rDF_1}{Gs(T_2 - t_w) + rDF_1} \quad (20)$$

The m series is convergent because $m < 1$ and, because in the limit, terms approach $(m/1)$ raised to some power.

Spheres. In the same way, the analysis for spherical solid shapes leads to the result

$$\frac{hA_F}{Gs} = (1 - M)\ln\left(\frac{T_1 - t_w}{T_e - t_w}\right)$$

$$+ M\Big[\frac{1}{2p}\ln\frac{(p^2 - pz_2 + z_2^2)(p+1)^2}{(p^2 - p + 1)(p + z_2)^2}$$

$$- \frac{\sqrt{3}}{p}\arctan\left(\frac{p - 2z_2}{p\sqrt{3}}\right)$$

$$+ \frac{\sqrt{3}}{p}\arctan\left(\frac{p-2}{p\sqrt{3}}\right)\Big] \quad (21)$$

where p is given by Equation 14.

If there is no zone of surface drying and $F_1 < F_e$ then $A_C = 0$ and

$$\frac{hA}{Gs} = (1 - M)\ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right)$$

$$+ M\Big[\frac{1}{2p}\ln\frac{(p^2 - pz_2 + z_2^2)(p+z_1)^2}{(p^2 - pz_1 + z_1^2)(p+z_2)^2}$$

$$- \frac{\sqrt{3}}{p}\arctan\left(\frac{p - 2z_2}{p\sqrt{3}}\right)$$

$$+ \frac{\sqrt{3}}{p}\arctan\left(\frac{p - 2z_1}{p\sqrt{3}}\right)\Big] \quad (22)$$

where p is given by Equation 16

and $z_1 = \sqrt[3]{\frac{F_1}{F_e}}$ and $z_2 = \sqrt[3]{\frac{F_2}{F_e}}$

For convenience in evaluating the potential differences in the above equations, the following substitutions are useful.

$$T_e - t_w = T_2 - t_w + \frac{rD}{Gs}(F_1 - F_e)$$

$$T_1 - t_w = T_2 - t_w + \frac{rD}{Gs}(F_1 - F_2) \quad (23)$$

Parallel flow driers

The analysis of the parallel flow adiabatic drier is similar to that for the counterflow drier, Figure 6. The appropriate results are tabulated below.

Surface drying zone; any shape

Slabs:

$$\frac{hA_C}{Gs} = \ln\left(\frac{T_1 - t_w}{T_e - t_w}\right) \quad (24)$$

Heat balances are as follows:

$$Gs(T_1 - T_e) = rD(F_1 - F_e)$$

$$Gs(T_1 - T_2) = rD(F_1 - F_2) \quad (25)$$

Interior drying zone

$$\frac{hA_F}{Gs} = -M\left(\frac{F_e - F_2}{F_e}\right)$$

$$+ [1 + M(1 + y^3)]\ln\left(\frac{T_e - t_w}{T_2 - t_w}\right) \quad (26)$$

where

$$1 + y^3 = \frac{Gs(T_e - t_w)}{rDF_e} \quad (27)$$

and M is given by Equations 8.

If there is no zone of surface drying and $F_1 < F_e$, then $A_C = 0$

$$\frac{hA}{Gs} = -M\left(\frac{F_1 - F_2}{F_e}\right)$$

$$+ [1 + M(1 + y^3)]\ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right) \quad (28)$$

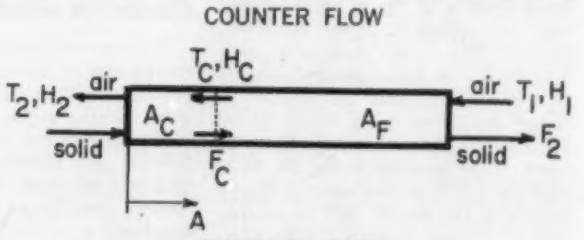

Figure 5. The free moisture of the solid reaches its critical value at the vertical dotted line representing the boundary between two zones (9). In the zone to the left of the boundary the rate of drying is not constant because the potential driving forces for heat and mass transfer are not constant. The dry bulb temperature of the air T_e decreases from *right* to *left*, and its absolute humidity H increases. Thus, the left end of the drier is called the "surface drying zone" (subscript C) instead of the "constant rate zone"; and the right side of the drier is called the "zone of interior drying" (subscript F). A is the area of the solid exposed to drying air.

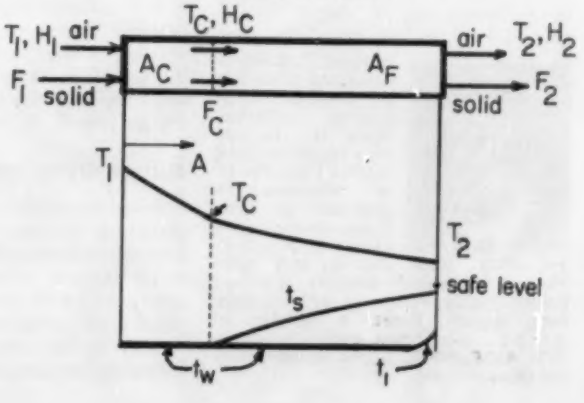

Figure 6. Temperature-sensitive materials may often be handled in parallel flow driers because the solid remains at the wet bulb temperature of the drying air for the duration of the surface drying period although the dry bulb temperature of the entering air may be very high. As drying proceeds the dry bulb temperature of the air T_e falls, the dry layers of the solid near the surface rise in temperature t_s. By carefully adjusting conditions, high surface drying rates can be attained without permitting the temperature of the solid to exceed safe levels. These temperatures are sketched in to show how the solid surface temperature is kept below a safe level.

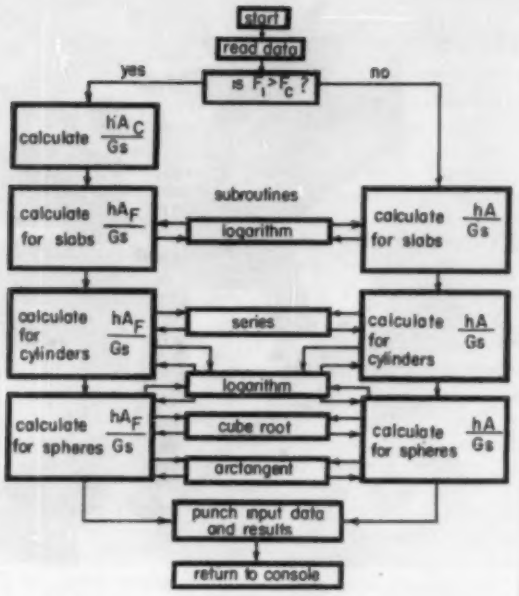

Figure 7. Flow sheet for digital computer programs.

Cylinders:

$$\frac{hA_F}{Gs} = \ln\left(\frac{T_c - t_w}{T_2 - t_w}\right) + \frac{M}{2}\left[\ln\left(\frac{F_2}{F_c}\right) \ln(1+n_2) + (n_c - n_2) - \frac{n_c^2 - n_2^2}{2^2} + \frac{n_c^3 - n_2^3}{3^2} - \text{etc.}\right] \quad (29)$$

where

$$n_2 = \frac{rDF_2}{Gs(T_1 - t_w) - rDF_1} \quad \text{and}$$

$$n_c = \frac{rDF_c}{Gs(T_1 - t_w) - rDF_1} \quad (30)$$

If there is no zone of surface drying and $F_1 < F_c$, then $A_C = 0$

$$\frac{hA}{Gs} = \ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right) + \frac{M}{2}\left[\ln\left(\frac{F_2}{F_c}\right) \ln(1+n_2) - \ln\left(\frac{F_1}{F_c}\right) \ln(1+n_1) + (n_1 - n_2) - \frac{n_1^2 - n_2^2}{2^2} + \text{etc.}\right] \quad (31)$$

where

$$n_1 = \frac{rDF_1}{Gs(T_1 - t_w) - rDF_1} \quad (32)$$

The n series converges since $n < 1$.

Spheres:

$$\frac{hA_F}{Gs} = (1-M) \ln\left(\frac{T_c - t_w}{T_2 - t_w}\right) - M\left[\frac{1}{2y} \ln \frac{(y^2 - yz_2 + z_2^2)(y+1)^2}{(y^2 - y + 1)(y+z_2)^2} + \frac{\sqrt{3}}{y} \arctan\left(\frac{2z_2 - y}{y\sqrt{3}}\right) - \frac{\sqrt{3}}{y} \arctan\left(\frac{2-y}{y\sqrt{3}}\right)\right] \quad (33)$$

where y^3 is given by Equation 27.

If there is no zone of surface drying and $F_1 < F_c$, then $A_C = 0$

$$\frac{hA}{Gs} = (1-M) \ln\left(\frac{T_1 - t_w}{T_2 - t_w}\right) - M\left[\frac{1}{2y} \ln \frac{(y^2 - yz_2 + z_2^2)(y+z_1)^2}{(y^2 - yz_1 + z_1^2)(y+z_2)^2} + \frac{\sqrt{3}}{y} \arctan\left(\frac{2z_2 - y}{y\sqrt{3}}\right) - \frac{\sqrt{3}}{y} \arctan\left(\frac{2z_1 - y}{y\sqrt{3}}\right)\right] \quad (34)$$

where $y^3 = \dfrac{Gs(T_1 - t_w) - rDF_1}{rDF_c}$ (35)

and $z_1 = \sqrt[3]{\dfrac{F_1}{F_c}}$ and $z_2 = \sqrt[3]{\dfrac{F_2}{F_c}}$

For the parallel flow drier the following equivalent potential differences may be needed:

$$T_c - t_w = T_1 - t_w - \frac{rD}{Gs}(F_1 - F_c)$$

$$T_2 - t_w = T_1 - t_w - \frac{rD}{Gs}(F_1 - F_2) \quad (36)$$

Summary

This article has outlined economical drying methods and presented procedures and equations for designing commercial driers without referring to dollar costs at any time. To use the equations, it is necessary to carry out an experimental test in a constant-conditions drier and to determine the critical free-moisture content and a suitable average value of the parameter M. The equations give results in terms of the surface area of solids which must be exposed in the drier. For the sake of economy this area should be as low as possible.

The drier volume must be sufficient to contain this much solid and allow for the passage of the drying air. The open cross-sectional area of the drier should be chosen to give the same mass velocity of the air flow as that used in the experimental test. As a final parameter, the drier length is equal to the necessary volume divided by the necessary cross-section. Arrangements should be made for conveying the solid at the rate D in such a way as to expose it to the air in the smallest practical particle size in a form as nearly spherical as possible. These principles indicate how the exposed area may be reduced.

Computer program available

To assist those who wish to carry out exploratory calculations, two digital computer programs are available, Figure 7. One is for countercurrent driers; the other is for parallel flow driers. Both are assumed to be adiabatic. Copies of the programs have been submitted to the A.I.Ch.E. computer library.

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JOHN C. CAMPBELL
Hudson Engineering Corporation

Field testing air-cooled heat exchangers

Use these recommended procedures to obtain reliable measurements for evaluation of performance of your induced or forced draft air exchangers.

AIR-COOLED HEAT EXCHANGERS CONSIST basically of tube bundles and fans to provide forced passage of air over the outer surface of the tubes. Normally, a hot fluid stream flows through the tubes and gives up heat to the air; in some less common applications, a cold stream of fluid flows through the tubes and gains heat from the air. The tubes are usually finned to provide additional surface for heat transfer. The tube bundles are generally mounted horizontally. It is customary to design the exchangers for upward travel of air, thus taking advantage of the natural tendency of warm air to rise. Air-cooled exchangers may be classified as either induced draft or forced draft. In the former type, the tube bundles are located on the suction side of the fans, in the latter type, the tubes are located on the discharge side of the fans.

Although the principles of removing heat with air are well known, little information on field testing of commercial air-cooled heat exchanger installations can be found in the literature. The purpose of this article is to present a method of testing which will yield accurate and dependable results. The techniques explained have been developed from a considerable number of tests on both commercial and development units.

Testing equipment

Temperature measurements should be made with ASTM mercury thermometers with an accuracy of ±0.2°F or better. A multi-point potentiometer should be used for the rapid reading of temperatures that cannot be measured easily and accurately with mercury thermometers. An adequate supply of calibrated thermocouples, connected to the potentiometers with

Field measurement of air delivery of an induced draft unit by two methods: traversing the exit air stream at upper right and the inlet air stream at lower left.

wires about 50 ft. in length, should be available.

For measurement of air velocities, Taylor Model 3132 vane type anemometers are recommended. Necessary accessories include an adapter and extension rod for remote readings, a shield to minimize wind effects when measuring air flowing from a tube bundle, and a watch to enable accurate timing of intervals of about 30 sec.

An inclined tube static pressure gauge calibrated for direct readings in inches of water with a range of 0 to 1.0 in. with 0.01 in. subdivisions and a total scale length of 8 to 12 in. is recommended.

Ammeters, voltmeters, and wattmeters for determination of the power consumed by the electric motors used for fan drivers are needed. The motors to be tested usually fall in the 5 to 75 horsepower, 110 to 440 volt class.

Experimental procedure

The rate at which heat is removed by an air-cooled unit is represented by the general heat transfer equation

$$Q = U A \Delta T \qquad (1)$$

Basically, the evaluation of performance consists in measuring Q and ΔT at test conditions, computing U from Equation 1, and correcting U to design conditions. The recommended procedures for experimental measurement of the necessary values are given below.

The testing operation may be divided roughly into four consecutive one-hour periods. First, the unit should be adjusted so that it will be operating as nearly as possible at design conditions. Second, equipment to be used for the measurements should be positioned and checked so that data can be taken without delay when the test period is started. Third, many of the necessary experimental measurements can be made before and/or after the test period proper, thus permitting more care and accuracy for the measurements. These measurements include air delivery, air static pressure drop, fan driver loads, fluid flow rate, and fluid pressure drop through the unit. The final period is the test itself. The following measurements should be recorded periodically using a time sequence such that errors resulting from changing conditions will be minimized:

1. Fluid inlet temperature, t_1
2. Fluid outlet temperature, t_2
3. Air inlet temperatures, T_1
4. Air outlet temperatures, T_2

Measurements

Some specific instructions to assist in securing reliable data are given below.

Air delivery. For induced draft units, the velocity of the air flowing over the surface of the tubes can be measured conveniently by traversing the air stream with an anemometer just before it reaches the tube bundle. The bundle face should be divided into imaginary rectangular areas about three ft. wide by four ft. long. Each should be traversed by moving the anemometer slowly back and forth for a period of 30 sec. To prevent error due to the restriction effect of the tubes, the traverse should be taken in a plane approximately 5 in. below the extremities of the fins. The product of the net face area of the bundle and the average velocity obtained will equal the actual volume of air per unit of time.

In some instances, obstructions below the bundle face may prohibit this method of air measurement. In such an event, air quantity can be determined by traversing the streams emitting from the fans serving the bundle or bundles. For this method, the plane bounded by the inner periphery at the top of the fan stack is divided into ten equal concentric areas numbered consecutively from 1 to 10 as shown in Figure 1. The ring is also divided into four quadrants. The air velocity is then measured at each point of intersection of the radii a, b, c & d with the inner peripheries of areas 1, 3, 5, 7, and 9 and at the center. The average velocities in combined areas 1-2, 3-4, 5-6, 7-8, and 9-10 are then obtained by averaging the four measurements taken along the inner peripheries of areas 1, 3, 5, 7 and 9, respectively. These velocities are plotted against the total areas bounded by the corresponding circles as shown in Figure 2. The net area below the resulting curve, between

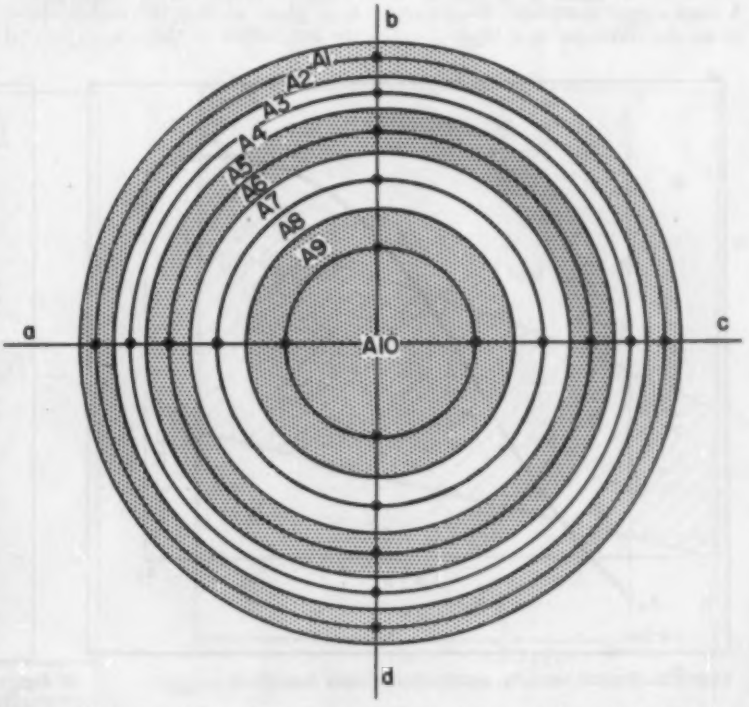
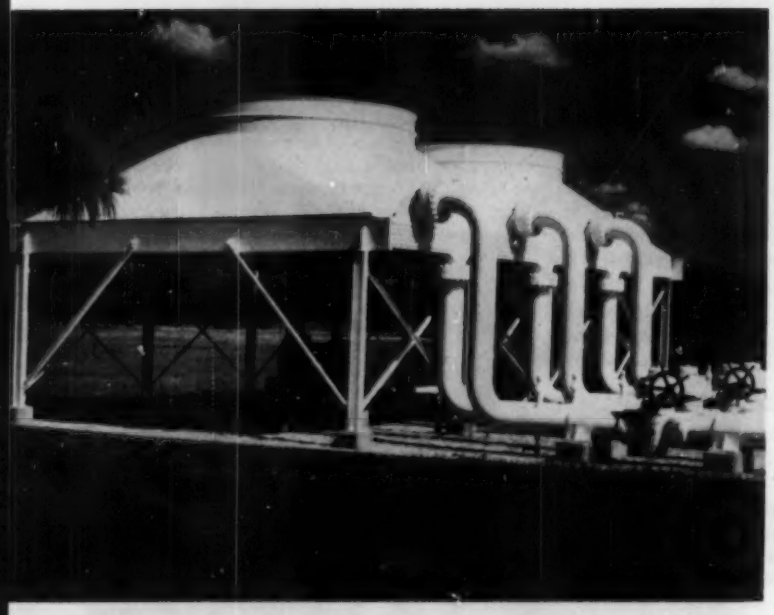


Figure 1. Location of air velocity measurement points across top of fan stack.



A typical installation of an induced draft air-cooled heat exchanger.

the limits A_0 and A_t, represents the actual volume of air delivered by the fan per unit of time. If desired, the foregoing procedure for determining air quantity may be simplified by averaging directly the 20 air velocities (the reading at the center of the fan is not used in this method) and multiplying the resulting number by the total fan ring area A_t. This gives a close approximation of the volume of air delivered per unit time.

For forced draft units, it is usually preferable to obtain air delivery by traversing the streams entering the fans. The procedure is similar to that explained for the traverse of the air streams emitting from the fans of induced draft units. In some instances it may be necessary to traverse the stream emitting from the bundles. In this case, the traverse must be made in a plane at least 12 inches above the extremities of the fins to prevent error due to the restriction effect of the tubes. To minimize error due to wind effect, a shield must be used.

Air static pressure drop. The static pressure drop resulting from the passage of air through the tube bundle should be measured at four points for each fan. Small holes slightly larger than the outside diameter of the probe should be drilled, and the probe inserted in the plenum between the tubes and the fan in such a position that the sensing end will be located in a comparatively "dead" portion of the air stream. This care in selecting a good location, in conjunction with a properly designed probe, will result in virtual elimination of error due to velocity effect.

Fan driver load. Electric motors are the most commonly used fan drivers. Power consumption for this type of drive can be measured directly. Other types of drives include steam turbine, gas turbine, oil turbine, gas engine, gasoline engine, and diesel engine. For most of these it is difficult to measure directly the power output and manufacturers' performance data must be relied upon.

Fluid flow rate. The measurement of the rate at which the fluid being cooled is flowing through the exchanger can be made by any of the generally accepted methods, such as

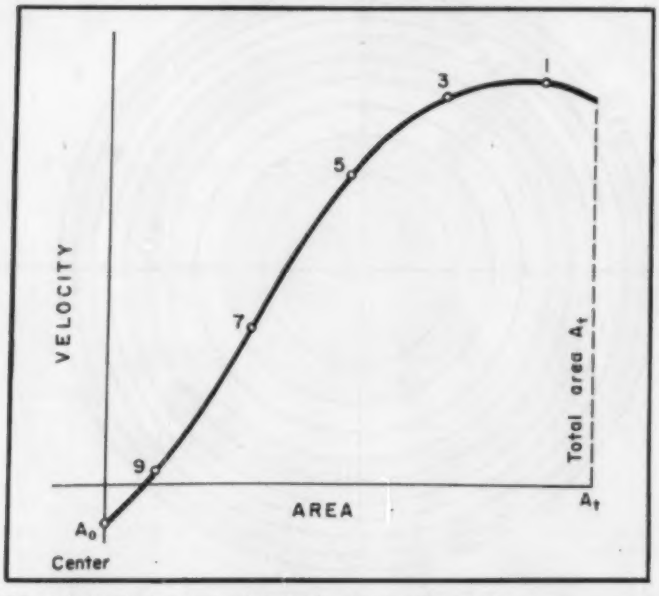


Figure 2. Typical velocity distribution across fan stack.

TIME, MIN.	MEASUREMENT*
0	t_1
4	t_2
8	T_1
12	T_2
16	t_1
20	t_2
24	T_1
28	T_2
32	T_1
36	t_2
40	t_1
44	T_2
48	T_1
52	t_2
56	t_1

*t_1 = Fluid inlet temperature
t_2 = Fluid outlet temperature
T_1 = Air inlet temperature
T_2 = Air outlet temperature

Figure 3. Suggested sequence for thermal measurements to minimize errors of changing conditions.

an orifice with a manometer, a pitot tube traverse, or a flow meter.

Fluid pressure drop. Ordinary pressure gauges are usually satisfactory for the measurement of fluid inlet and outlet pressures. Increased accuracy in the determination of pressure drop can be obtained by the following procedure:

1. Read the gauges in their normal positions and subtract to obtain ΔP_1
2. Switch the gauges, re-read, and subtract to obtain ΔP_2
3. Average ΔP_1 and ΔP_2

For the measurement of very small pressure drops, pressure gauges are sometimes unsatisfactory, particularly when the operating pressure is high. One of the following methods should be used: differential pressure meter, dead-weight tester, or high-pressure manometer.

Inlet and outlet temperatures. These measurements should be taken systematically to minimize errors resulting from changing conditions. A suggested time sequence incorporating the desired "bracketing" effect is presented in Figure 3.

For the measurement of fluid inlet and outlet temperatures, thermocouples or mercury thermometers should be inserted in thermowells located in the inlet and outlet fluid lines. The following precautions will assist in obtaining accurate readings:

1. If several thermowells are available, those nearest the cooler should be used.
2. The thermometers or thermocouples should be installed sufficiently early to permit reaching equilibrium conditions before the start of the test period.
3. A suitable seal material should be placed around the thermometers or couples to minimize the effects of the surrounding atmosphere.
4. The thermometers or thermocouples should be positioned so that the sensitive elements are located near the centers of the lines.
5. If thermocouples are used, precautions should be taken to insure that shorting does not occur as the result of simultaneous contact of the tip and another point on the couple with the thermowell metal.

For the measurement of inlet air temperatures, it is recommended that about eight thermometers or thermocouples be spaced around the unit. Precautions must be taken to prevent erroneous readings due to direct contact of sunlight with the sensitive elements of the thermometers or thermocouples, or due to radiation from the tube bundles or other hot substances in the vicinity.

The techniques required for the measurement of air outlet temperatures differ for induced draft and forced draft units.

For induced draft units, the fans are located above the tube bundles, and measurements of exit air temperatures require temperature traverses of the air streams emitting from the fans. For large fans, it is recommended that the thermocouples be used to measure two points along each of four radii as indicated in Figure 4. The precautions mentioned for inlet air temperatures should be observed for these measurements, and in addition care must be taken to prevent erroneous readings due to dilution of the air stream with fresh air. The thermocouples should be located a few inches below the top of the fan stack and in the main body of the air stream. Some fans produce reversed air flow near the periphery and in the center of the stack. These areas should be checked before the test and avoided. The measurements of the eight points may be made by locating eight thermocouples or by using an extension rod for movement of a single couple from point to point. If the latter method is used, sufficient time should be allowed after movement to permit the thermocouple to reach equilibrium conditions.

For forced draft units, the tube bundles are located above the fans, and a temperature traverse of the air stream emitting from the tubes must be made. A satisfactory method is the use of an extension rod for the movement of a single couple from point to point. It is recommended that at least eight points be measured

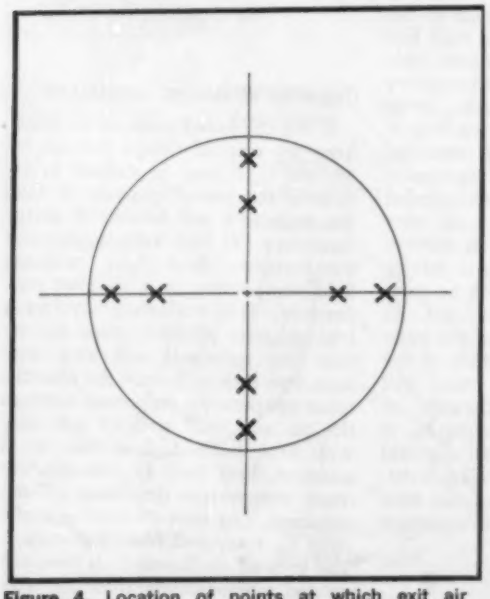


Figure 4. Location of points at which exit air temperatures should be measured in induced draft units.

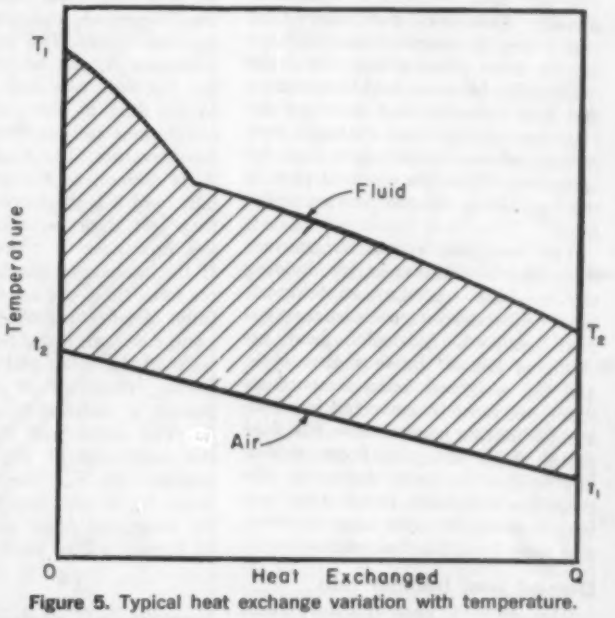


Figure 5. Typical heat exchange variation with temperature.

for a tube bundle 8 ft. wide by 24 ft. long. For other size bundles, the number of points may differ as suitable. A shield must be used to protect the thermocouple from the effects of wind, sun, and radiation.

Computation of results

The rate of heat removal Q, or heat load at test conditions, is determined independently from the air-side and fluid-side measurements. The air-side heat load is simply the product of the air quantity and the air enthalpy change; the fluid-side heat load is the product of the fluid quantity and the fluid enthalpy change. These two values should agree and a difference of greater than 10% is sufficient to indicate that the test should be repeated. In this event, an attempt should first be made to determine the reasons for the heat balance error.

The effective mean temperature difference ΔT between the air stream and the fluid from which heat is being removed is determined from the test measurements of air and fluid inlet temperatures and from a knowledge of the relationship between enthalpy and temperature as the two streams progress through the exchanger. The latter may be presented as a plot of temperature versus heat removed for both streams (Figure 5). Since the air stream does not undergo a phase change, and since its specific heat change is usually negligible over the temperature range involved, a straight line relationship between air temperature and heat removed is essentially correct. However, the fluid from which heat is removed may undergo one or more phase changes and the relationship between fluid temperature and heat removed may therefore deviate appreciably from a straight line. A heat-release curve must then be computed. Thus, an essential part of the test data is the composition of the fluid.

The weighted mean temperature difference is determined by dividing the area between the two temperature–heat removed curves by the total heat removed. Air-cooled heat exchangers are of the cross-flow type, and the weighted mean temperature difference must be corrected for deviation from true counter flow. For fluid passes above four, this factor is usually unity. In some instances, the cross-flow correction factor itself may vary appreciably with heat removed, and must be applied accordingly.

Over-all heat transfer rate

The over-all heat transfer coefficient U at test conditions is computed from Equation 1, using the heat transfer area and the test values of Q and ΔT explained above. It is customary to base this coefficient on the external surface of the bare tubes, rather than on the external surface of the fins.

The over-all heat transfer coefficient may be written as

$$U = \frac{1}{R_i + R_f + R_m + R_o} \qquad (2)$$

where:

R_i is the inside fluid film resistance

R_f is the fouling resistance, or resistance due to static deposits on the inner wall of the tubes

R_m is the resistance of the metal tube wall

R_o is the air film resistance

John C. Campbell is with Hudson Engineering. His activities include rating, design, testing of industrial water cooling towers and air-cooled exchangers, and R&D on heat transfer characteristics of finned tubing. Campbell spent six years, until 1954, in catalytic cracking research with Texaco. He is a charter member of Houston's new Process Heat Exchanger Society. Campbell received his B.S. degree in chemical engineering in 1948, from the U. of Missouri.

The process of determining U at design conditions consists of evaluating the individual resistances at test conditions and adjusting them to design conditions. The inside fluid film resistance R_i can be calculated from the test flow rate and the properties of the fluid at test conditions, using correlations and methods presented in the literature. The fouling resistance R_f is difficult to evaluate experimentally, and it is therefore recommended that test data be taken soon after the exchanger is placed in service. If the exchanger has been in service for some time, the tubes may be carefully cleaned prior to the test. In some cases, an inspection of the inner walls of the tubes and a study of the fouling character of the fluid will permit a satisfactory estimation of R_f. The metal wall resistance R_m is the reciprocal of the wall thermal conductivity K_m. The air film resistance, R_o, at test conditions can then be computed from a rearrangement of Equation 2 to yield

$$R_o = \frac{1}{U} - R_i - R_f - R_m \qquad (3)$$

The individual resistances are then adjusted to design conditions. For convenience, the resistances at design conditions are identified by a prime. The values of R_i', R_f' and R_m' will be the same as presented in the original design of the exchanger. The test value of R_o must be adjusted to design fan driver horsepower. This involves adjusting air quantity to design horsepower, computing corresponding face velocity, and determining R_o' by means of the equation:

$$R_o' = R_o \left(\frac{a + b\ V_1^c}{a + b\ V_2^c} \right) \qquad (4)$$

where:

V_1 = air velocity across face of tubes at test conditions

V_2 = air velocity across face of tubes at design horsepower

a, b, & c are constants identifying the tube characteristic

For most tubes the value of the constant a may be neglected and c may be considered equal to 0.50. Equation 4 may thus be simplified to:

$$R_o' = R_o \sqrt{\frac{V_1}{V_2}} \qquad (5)$$

The over-all heat transfer coefficient expected at design conditions, U', may then be computed from the formula:

$$U' = \frac{1}{R_i' + R_f' + R_m' + R_o'} \qquad (6)$$

Capacity at design conditions

If the computed value of U' differs from the original design over-all coefficient U, it may be desired to determine the actual quantity of fluid the exchanger will handle at design conditions of fluid inlet and outlet temperatures, fluid inlet pressure, fluid composition, and air inlet temperature. This evaluation involves a trial-and-error solution, since the inside film resistance will vary with mass flow rate, and since the effective mean temperature difference between the air and fluid streams will vary with heat load. A flow rate W is assumed, heat load Q and effective mean temperature difference ΔT determined, and over-all service coefficient U_s computed from Equation 1. The over-all coefficient U is then calculated independently from the individual resistance, using Equation 2. Values of W are re-assumed and the computations repeated until $U_s = U$.

J. A. Duffie, *Univ. of Wisconsin*
G. O. G. Löf, *Consultant, Denver, Colo.*
E. M. A. Salam, *Cairo Univ., Egypt*

Solar heat exchangers

The up to the minute results of studies on methods to improve performance and reduce costs.

Solar energy may be used in several types of processes; such as, thermal, photochemical, and photoelectric. In the photo processes the spectral distribution of the incident energy is important, and usually only the short wave (high energy) portion of the solar spectrum (the visible and ultraviolet) is effective. However, the energy of the total available solar spectrum, including the near infrared, is useful in thermal processes. All thermal processes require solar heat exchangers to intercept the radiation and convert it for the purpose at hand. This article is concerned with the analysis of energy balances for these exchangers.

A solar heat exchanger differs in several respects from more conventional exchangers. The latter usually accomplish a fluid-to-fluid exchange with heat transfer rates of thousands of B.t.u./(hr.)(sq.ft.), and with radiation an unimportant factor. In the solar exchanger, energy transfer is from a distant source of radiant energy to a fluid, and the flux of incident radiation (without optical concentration) is, at best, about 350 B.t.u./(hr.)(sq.ft.). It has a wave length range from 0.3μ to 2.5μ, considerably shorter than that of the emitted radiation from most energy absorbing surfaces. Thus the development of solar heat exchangers presents the unique problems of low energy fluxes and the predominating importance of radiation.

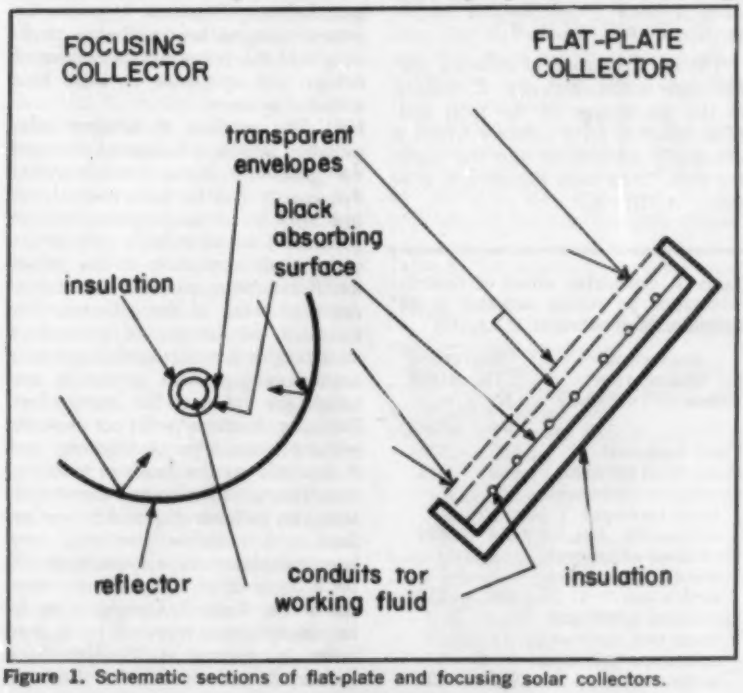


Figure 1. Schematic sections of flat-plate and focusing solar collectors.

Widespread use of solar energy cannot be expected to develop until energy from this source becomes competitive with other sources. Recent papers *(1-3)* have explored some of the pertinent economic considerations. To minimize the cost of the solar energy transferred to the working fluid, solar heat exchanger studies are directed toward: improving the performance of the heat exchanger system and thus reducing area requirements for a specified output; reducing the first costs of the equipment per unit of heat transfer area; and minimizing maintenance and operating costs.

Solar heat exchangers may be used with or without radiation concentrators. Flat-plate solar heat exchangers, usually termed "flat-plate collectors," have the area of the solar energy absorber the same as the area intercepting solar radiation. Focusing collectors usually have concave reflectors to concentrate radiation falling on the total area of the reflector onto a heat exchanger of smaller surface area, thereby increasing the energy flux on the solar energy absorber. The important parts of solar heat exchangers, Figure 1, are: the "black" solar-energy absorbing surface, with means for transferring the absorbed energy as heat to a fluid; envelopes, transparent to solar radiation, around or over the solar absorber surface which reduce convection and radiation losses to the atmosphere; and back insulation to reduce conduction losses, if the geometry of the system permits.

Flat-plate exchangers are now best suited for moderate temperature use, up to 100 or 150°F above ambient temperature. They have the advantages of transferring both direct and diffuse solar radiation to the working

fluid, not requiring orientation toward the sun, and apparently costing less than the combination of a focusing reflector and heat exchanger. The principal present applications of these units are in solar water heating systems; potential uses are in house heating and air conditioning.

The focusing collector seems most practical for processes where higher temperatures are required. Focusing collectors with low concentration ratios (2 to 100—the ratio of projected reflector area to solar energy absorber area) have been used for low pressure steam generators and solar cookers. By use of concentration ratios of 10,000 to 50,000, solar furnaces can develop focal temperatures up to 8000°F. All of these collectors utilize only the direct radiation, and most designs require intermittent or continuous movement to "track" the sun.

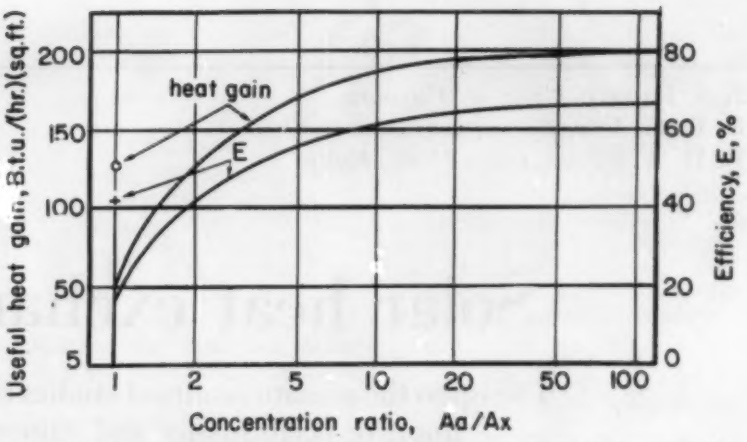


Figure 2. Variation of heat gain per square foot of aperture A_a with concentration ratio for an idealized example. Product $HR\tau\alpha$ assumed constant at 200 Btu./(hr.)(sq.ft.) and q_{th} = 150 Btu./(hr.)(sq.ft.) of exchanger area A_x. Points 0 and + indicate performance of a flat plate collector ($A_a = A_x$) which can also collect diffuse radiation.

Collector energy balances

A general statement of the energy balance for solar collectors can be written:

$$HR\frac{A_a}{A_x}r\tau\alpha = q_u + q_{th} + q_{hc} \qquad (1)$$

H = rate of incidence of solar radiation on a unit area of horizontal surface, B.t.u./(hr.)(sq.ft.). For a focusing collector, H includes only the direct component of the incident radiation.

R = factor to convert radiation on a horizontal plane to that on the plane of the aperture of the collector.

A_a = area of aperture of collector, sq.ft.

A_x = solar energy absorbing area of the solar heat exchanger, sq.ft.

r = ratio of the reflected radiant energy reaching the heat exchanger to the direct radiation incident on the reflector, (effective reflectivity).

τ = solar transmissivity of any transparent envelopes surrounding the heat exchange surface.

α = absorptivity of the "black" absorbing surface of the heat exchanger for solar radiation.

q_u = rate of useful heat transfer to a working fluid in the solar exchanger (collected energy), per unit area of the solar heat exchanger A_x, B.t.u./(hr.)(sq.ft.).

q_{th} = rate of thermal losses from the absorbing surface, including those to the atmosphere and surroundings by reradiation and convection, and by conduction through back insulation, supports for the absorber, etc. per unit area of the solar heat exchanger A_x, B.t.u./(hr.)(sq.ft.).

q_{hc} = rate of energy storage or depletion in the heat exchanger per unit area of the solar heat exchanger A_x, if not operating at constant temperature, B.t.u./(hr.)(sq.ft.).

The usual measure of collector performance is the efficiency, E, defined as the percentage of the total incident radiation on a collector which is ultimately transferred into the working fluid. Thus from Equation 1, $E = 100q_u A_x/HR A_a$.

Table 1. Calculated effect of collector orientation on annual radiation at 35° Latitude, Southwestern U.S.A. *(6)*

Collector Orientation (Mode of Tracking)	Radiation, Thousands B.t.u./sq.ft.	
	Total	Direct
Fixed, horizontal	585	470
Fixed, tilted 35° south	680	545
Continuous adjustment about horizontal north-south axis	814	654
Continuous adjustment about axis parallel to earth's axis	898	717
Continuous adjustment about two axes to maintain normal solar incidence	921	738

For a stationary flat-plate solar exchanger the reflectivity term disappears from the heat balance, $A_a = A_x$, and R varies throughout the day. For a focusing collector the concentration ratio A_a/A_x is greater than unity, and the area for thermal heat loss is smaller than the area intercepting solar radiation. Energy balances of this type have been studied by Hottel and Woertz *(4)*, and Tabor *(5)*.

Collector performance factors

A term-by-term examination of the heat balance, Equation 1, points up several unusual heat exchange problems and the important principles of design and operation of solar heat collector systems.

HR. The product of incident solar radiation rate on a horizontal area and the geometric factor for converting this energy flux to that received per square foot of intercepting surface (aperture) is controllable only by location and orientation of the collector. R can be maximized by continuous positioning of the collector. The economic advantages of permanent mounting of flat-plate exchangers in a south-sloping position appear to outweigh the value of the energy lost. Focusing systems will not operate without some type of tracking, and R depends on the mode of tracking. Annual total radiation and direct radiation, on surfaces disposed in various fixed and movable positions, have been calculated for a latitude of 35° by Eibling *et al. (6)*, and are summarized in Table 1. Compared to the annual radiation received by a fixed horizontal surface at 35° latitude, a surface of fixed tilt of 35° to the south

Table 2. Effective reflectivity, r, for several experimental focusing collectors.

Reflector Type; and Surface	A_a/A_x	Specular Reflectivity of Surface	Shape Positioning Factor	Effective r
4 ft. aperture paraboloid; Vapor-deposited Al on "Mylar" film; manually adjusted	25	0.80	0.74	0.59
Same reflector, smaller exchanger	62	0.80	0.56	0.45
Parabolic cylinder, 7 ft. aperture, 12 ft. length; Polished Al; clock drive	10	0.74	0.95	0.70
12 ft. aperture spherical; Aluminized "Mylar" film; manually adjusted	50	0.80	0.79	0.63

(northern hemisphere) receives 16% more radiation; a sun-tracking surface receives 57% more.

A_a/A_x. For a flat-plate solar heat exchanger $A_a = A_x$ and the maximum energy flux of approximately 350 B.t.u./(hr.) (sq.ft.) limits the net useful heat transfer rate in the exchanger. More energy can be supplied to the exchanger by focusing on it the radiation incident on a reflector (or lens) substantially larger than the heat exchange surface. The ratio of focusing reflector aperture to heat exchanger area can range from unity to many thousands; in the higher range the solar heat exchanger may have energy flux rates comparable with those in conventional exchangers.

Since thermal losses from the large surface of a flat-plate solar heat exchanger increase with temperature, low useful energy delivery at high temperatures results. By increasing A_a/A_x, solar heat exchanger area and thermal losses are reduced, and higher heat delivery temperatures may be obtained. Reflection losses and failure to collect diffuse radiation result in lower heat recovery by a focusing system of low concentration ratio than by a nonfocusing system operating at the same temperature; but increased heat recoveries may be achieved with higher values of A_a/A_x. Variation of useful heat recovery per square foot of collector aperture area A_a, with A_a/A_x, is shown in Figure 2 for an idealized example with constant effective reflectivity and heat exchanger temperature. The useful heat and efficiency curves approach asymptotes representing zero thermal losses at zero heat exchanger area.

r. Reflectivity loss for a focusing system may be due to lack of complete specularity of the reflective surface, imperfect shape of reflector, and improper focusing or positioning of reflector. High specular reflectivity has commonly been achieved by use of metal deposits or coatings on other metals or glass. Anodized aluminum sheets have been used in focusing units, particularly of the parabolic cylinder type (7), and reflectivities of 0.85 can be obtained with this material. Vacuum-metallized plastic films, such as aluminized polyester film, may have reflectivities (through half-mil plastic) of 80% or more; this material when supported on a rigid backing forms an acceptable reflector surface.

Orientation of the focusing reflector with respect to the sun and the size and position of the heat exchanger govern the fraction of specularly reflected energy reaching the exchanger. Enlargement of the heat exchanger, to compensate for inaccuracies in reflector shape and positioning, increases thermal losses and exchanger costs, but may permit reflector economies which more than offset these advantages. Data on effective reflectivities, summarized in Table 2, indicate that lack of specular reflectivity and the shape-positioning factor are significant, and that effective reflectivity varies widely.

τ. Radiation and convection loss from the heat exchange surface to the sky and surrounding air may be reduced by covering the absorbing surface with one or more transparent covers. These layers of glass or plastic reduce convection losses by providing closed air spaces between the hot exchanger surface and the surroundings. Since many of these materials are almost completely opaque to the long-wave radiation emitted from sources at temperatures of a few hundred degrees, they may also constitute good insulation for radiation loss reduction. However, the envelopes do not transmit all of the incident solar radiation because of absorption and reflection. This effect is shown in Table 3.

To improve transmissivity for solar radiation, glass may be treated by forming on its surface a thin mineral film having a thickness approximating one-fourth the mean wave length of the incident radiation; multiples of this wave length are then nearly perfectly transmitted. A thin film of silica may be produced on glass by controlled dissolving of alkalis from the glass in hydrofluoric acid solutions. The process apparently produces a film of graded thickness or composition, for it reduces reflectivity greater than would be predicted from consideration of interference effects on narrow bands of the total solar spectrum. Table 3 indicates the effects of this treatment.

Recent developments in transparent coverings for solar heat exchangers include clear plastic films of improved weatherability (8). Thin films (0.0005 to 0.005in. thickness) of polyesters, polyfluor carbons, and other synthetics have been employed. Whether they will have adequate long-term strength, wind-resistance, freedom from dust collection, and other desirable properties remains to be determined. It may be possible that these films may also be rendered largely nonreflective by surface-treating methods.

The advantage of using low-reflec-

Table 3. Transmissivity for solar radiation of glass and plastic films.

Material	Thickness, Inches	Percent Normal Incidence Transmitted	Ref.
Single-strength white glass	0.09	0.89	(4)
Same, 3 layers	0.09 (ea)	0.70	(4)
"Teflon-100 X" fluorocarbon film	0.002	0.97	(8)
Weatherable "Mylar" film	0.002	0.85	(8)
Single-strength white glass, B	0.094		
Spectrum range:			
U.V. (0.325 to 0.375μ)		0.74	
Visible (0.40 to 0.70μ)		0.91	
I.R. (0.80 to 1.00μ)		0.90	
Mean Total Solar		0.90	
Same glass, surface treated by etching process	0.092		
Spectrum range:			
U.V. (0.325 to 0.375μ)		0.78	
Visible (0.40 to 0.70μ)		0.97	
I.R. (0.80 to 1.00μ)		0.94	
Mean Total Solar		0.955	

tion glass in an overlapped plate solar heat exchanger is indicated by experimental measurements of heat recovery for operation during a day when 2200 B.t.u./sq.ft. radiation was incident on the collectors. A three-cover collector had a reflection loss of 21% and a useful recovery of 33%; a similar exchanger with surface-treated glass had a reflection loss of 10% and a useful heat gain of 44% of the incident radiation.

α. For maximum efficiency the solar heat exchanger should have the highest possible absorptivity for solar radiation. The black surfaces must be stable at maximum operating temperatures and able to withstand necessary handling. Most of the surfaces which have a high absorptivity for short-wave solar radiation also have a high emissivity for long-wave radiation. However, as noted below, surfaces with high values of α and low values of emissivity for long-wave radiation can be produced and advantageously used in solar heat exchangers.

q_{th}. The thermal loss from a solar heat exchanger is the sum of convection and radiation transfer from the absorber to the surrounding atmosphere or to a transparent envelope, and conduction loss through insulated backing on the absorber and through edges or supports of the exchanger. Per square foot of absorber,

$$q_{th} = h(T_B - T_S) + F_A F_E (T_B^4 - T_S^4) + \frac{k}{l}(T_B - T_A) \quad (2)$$

h = convection coefficient for loss from the absorbing surface to atmosphere or to an enclosing transparent envelope.

T_B = mean absolute temperature of absorbing surface.

T_S = absolute temperature of surroundings (ambient temperature or the temperature of the nearest envelope).

F_A = shape factor (= 1 for flat plate, uncovered exchangers).

F_E = emissivity factor; a function of the emissivity of the absorbing surfaces for long-wave radiation, ϵ_B, and the emissivity of the surrounding envelope, ϵ_G, if there is one. For flat plate heat exchangers with a cover,

$$F_E = \frac{1}{\frac{1}{\epsilon_B} + \frac{1}{\epsilon_G} - 1}$$

Duffie

Salam

Lof

John A. Duffie is Associate Professor and assistant director, Engineering Experiment Station, U. of Wisconsin. A project associate in the Solar Energy Research Program at the university, Duffie is an editor and contributing author of Solar Energy Research.

Ehab M. A. Salam has a B.S. and M.S. in Physics, U. of Cairo, Egypt. Now on the staff of the Desert Institute, Mataria, Egypt, he was research assistant at the U. of Wisconsin from 1956-58.

George O. G. Lof is a consultant on solar energy and water resources. He is a former head of the Chemical Engineering Department, U. of Colorado, and Director, Institute of Industrial Research, Denver U.

For uncovered collectors F_E is usually taken as ϵ_B.

k/l = thermal conductivity divided by thickness for any conduction losses that may be applicable.

T_A = absolute temperature at the back of the insulation.

A development of major interest in solar heat exchangers has been the reduction of radiation losses by use of surfaces having low long-wave emissivities, ϵ_B, while retaining high absorptivities for short-wave solar radiation. These selective surfaces consist of thin layers of semiconductors such as cupric oxide (opaque to short-wave solar radiation but transparent to long-wave reradiation) over polished metallic surfaces having low long-wave emissivity. The coatings may be prepared by several methods, including controlled oxidation of the base metal by dipping in oxidizing solutions *(9)*, by oxidation of plated metal films *(10)*, and by decomposition at elevated temperature of deposits of metal salts applied by spraying aqueous solutions on the polished base metal *(11)*. Experimental values of α and ϵ_B for several film-metal combinations are shown in Table 4.

Low emissivity is most advantageous with high absorber temperatures and few transparent envelopes. Reduction in emissivity permits the use of fewer transparent covers, thereby reducing transmissivity loss and heat exchanger cost. The effects of ϵ_B and number of envelopes on the sum of convection and radiation losses, calculated at an ambient temperature of 60°F by methods of Hottel and Woertz, are shown in Figure 3.

The term k/l is treated by conventional methods. The optimum thickness of insulation in a particular application depends on the value of the heat saved by incremental additions of insulation and the cost thereof. The recent development of foamed or cellular insulating materials that will not wet is potentially important, as solar exchangers are exposed to all types of weather.

An important consideration is the number of transparent envelopes over the absorbing surface. Increasing their number decreases convection and radiation loss by increasing T_S in Equation 2, but adds solar transmission loss. The optimum number of covers depends on the transmissivity of the cover material, the difference in temperature between solar absorber and ambient air, ϵ_B, and the concentration ratio, A_a/A_s.

A further objective in the design of solar collectors of both types is to minimize thermal losses by reducing the temperature difference between the solar absorber surface and the working fluid. In addition to the usual resistances to heat transfer from metal to fluid, temperature gradients in portions of the solar absorber sheet which may not be in contact with the fluid must also be considered. In focusing systems, these gradients may be high due to non uniform distribution of the reflected radiation on the heat exchanger. For example, a 12-ft. spherical reflector-heat exchanger combination, with $A_a/A_s = 50$, has an energy-absorbing surface comprising a copper sheet, to which copper tubes are soldered on one-inch centers.

Table 4. Absorptivities for solar radiation and emissivity for long-wave radiation (from surfaces at 80 to 110°C) for several selective surfaces.

Metal Base	Coating	Wt. Coating, mg./sq. cm.	α	ϵ_B	Ref.
Polished Cu	CuO	0.055	0.80	0.09	(9)
Polished Cu	CuO	0.22	0.89	0.19	(9)
Steel	FeO-Fe_2O_3	0.18	0.92	0.21	(9)
Plated nickel	CuO	0.35	0.86	0.21	(9)
Polished aluminum	CuO	0.30	0.93	0.11	(11)
Aluminum	CuO	—	0.85	0.11	(5)

Table 5. Performance of two-cover flat-plate solar heat exchangers, from hour-by-hour calculations based on Madison clear day radiation data. Exchangers tilted 35° to the south.

Conditions	Clear Summer Day T_B=220, T_A=90 HR=2280 B.t.u.	Clear Summer Day T_B=160, T_A=90 HR=2280 B.t.u.	Clear Winter Day T_B=120, T_A=20 HR=1940 B.t.u.
	Efficiency, %	*Efficiency, %*	*Efficiency, %*
Standard glass, ϵ_B=0.95	19	40	34
Standard glass, ϵ_B=0.10	40	51	47
Low refl. glass, ϵ_B=0.95	29	51	45
Low refl. glass, ϵ_B=0.10	51	62	58

In one experiment, absorber surface temperature varied from 320 to 600° F when the heat transfer liquid was at 300° F. Temperature differences of 300° (which are excessive) result in excessive thermal losses, and for boilers would result in low heat transfer coefficients due to film boiling.

q_{he}- Intermittency of solar energy supply is unavoidable. Energy used to preheat an exchanger from low night-time temperature to its minimum operating temperature represents irrecoverable heat loss each day of operation. It is therefore usually advantageous to minimize the heat capacity of the solar heat exchanger. Typical values of equivalent heat capacity of solar exchangers with glass covers are 0.5 to 1.5 B.t.u./(sq.ft.)(°F temperature change of the solar absorber surface). Use of plastic glazing and low density insulation in exchangers permits substantial reduction in heat capacity. For example, substitution of plastics and low density insulation for glass and glass foam insulation can result in a useful daily heat recovery increase of 15%, for a flat-plate collector generating low pressure steam.

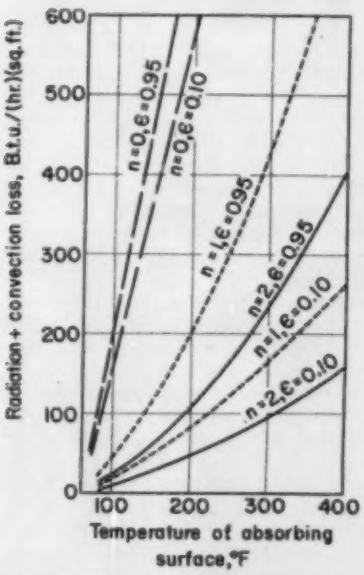


Figure 3. Thermal losses by convection and radiation from solar energy absorbing surface as function of temperature of the surface and number of covers n for emissivities of 0.95 (nonselective surface) and 0.10 (selective surface). Reduction in collection due to transmission losses not shown.

Recent developments

The separate effects of selective surfaces, low reflectance covers, and improvements in effective reflectivity result in moderate increases in solar heat exchanger performance; their combined effect can be a major gain in collection efficiency.

Table 5 shows the computed performance of flat-plate solar heat exchangers having absorber surfaces of high and low emissivities and having two covers of standard and low reflectance glass. Solar heat exchanger efficiency is shown for a clear summer day at conditions representing applications to: an absorption air conditioner (T_B = 220°F); a water heater (T_B = 160°F); and for a clear winter day in a space heater (T_B = 120°F). The combination of low reflectance glass and low emissivity is seen to be most effective at high heat exchanger temperatures and large temperature differences between the exchanger and ambient air.

The improvements in performance which can be achieved by increasing the reflectivity of a focusing reflector and reducing the emissivity of the heat absorbing surface are shown by Table 6. The gain in efficiency through use of a cover is less significant, but at high temperature, appreciable advantage is secured. A surface-treated cover material would enhance this improvement. The examples shown in Tables 5 and 6 are not intended to represent optimum designs for the indicated conditions, as the costs of the specified improvements have not been taken into consideration.

Table 6. Hourly performance of reflector-exchanger with A_a/A_s = 50.

Data marked • is experimental for a collector of 110 sq. ft. area, with incident direct radiation of 33,000 B.t.u./hr. Other figures are based on experimental data corrected for estimated thermal and optical losses.

Conditions τ	Conditions ϵ_B	Collection Efficiency, E, % T_B=380°F	Collection Efficiency, E, % T_B=500°F
No covers on exchanger			
0.63	0.95	43•	34
0.80	0.95	59	50
0.63	0.10	48	45
0.80	0.10	63	57
One cover, τ = 0.90			
0.63	0.95	45	40
0.80	0.95	59	54
0.63	0.10	48	45
0.80	0.10	62	59

The economics of solar energy use must be evaluated in terms of a specific location and application, and are subject to change as solar technology develops and as the cost of energy from competing sources changes. In a previous paper *(1)* the authors examined some of the economic factors in solar space heating, air conditioning, and power generation, concluding that solar energy should become competitive with conventional energy sources for these purposes in many applications as the allowable costs of solar heat exchangers ($1-4/sq.ft. of collector for space heating in the United States) are potentially attainable. Since solar energy has economic promise under the proper conditions, these new developments in solar processes should be significant in bringing this source of energy closer to general use.

ACKNOWLEDGMENT

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D. Cornell, *Oklahoma State Univ.*
W. G. Knapp *and* J. R. Fair,
Monsanto Chemical Co.

Mass transfer efficiency —packed columns—part 1

Here, for general use, are correlations of liquid and vapor phase transfer units. HETP methods cannot be extended to such general use.

The use of packed columns for continuous contacting of vapors and liquids is well established in the chemical industry. Design by the "height of a transfer unit" method is a desirable and established practice. Such designs require a knowledge of the height of a transfer unit for both the liquid and gas films. A knowledge of the design procedures, as well as their advantages and disadvantages, as set forth by such authors as Leva (*10*) is assumed herein. This article presents correlations of published data for H_L and H_G together with new data on commercial scale packed column distillation studies.

Liquid phase mass transfer

The H_L data of Sherwood and Holloway (*13*) are widely used for design purposes. Additional work has since appeared, however, that extends the scope of this early study.

Values of the height of a liquid film transfer unit, H_L, are usually obtained experimentally by the absorption or desorption of a slightly soluble gas from a liquid film flowing over a tower packing, countercurrent to a stream of air. Under such conditions, concentration changes in the gas are negligible and no gas film resistance is considered to exist. A summary of reported H_L values, together with test conditions, is presented in Table 1.

Experimental variables study

Variables considered to affect the height of a liquid transfer unit are: packed height, gas velocity, column diameter, liquid physical properties, packing type, and packing size.

Packed height. Sherwood and Holloway (*13*) concluded that variations in packed height had a negligible effect on H_L. Van Krevelin and Hoftijzer (*16*) assigned an exponent of ⅓ to packed height in correcting H_L values to other packed heights. Since liquid rates of about 1000 lb./(hr.)-(sq. ft.) or lower are of greatest interest in distillation, the effect of packing height on H_L at $L = 1000$ was plotted in Figure 1. The average slope of these lines is 0.15. This value is recommended in place of the ⅓ exponent selected by Van Krevelin and Hoftijzer since it was obtained under carefully controlled experimental conditions using commercial size equipment.

Gas velocity. Sherwood and Holloway showed that gas rates up to the loading point have no effect on H_L. Above the loading point, H_L decreases with gas rate, probably because of liquid phase disturbance. Very little information is available on the effect of high gas rates on H_L values. Sherwood and Holloway present data on 1.5-in. Raschig rings as follows:

Percent Flood	H_L, ft.	C
13.5	0.92	1.00
51.2	0.88	0.96
77.7	0.56	0.61

where C is a correction factor for H_L.

Figure 2 shows a plot of these values of C which may be used to correct H_L at low gas rates for the effect of high gas velocities. In the absence of more complete information, Figure 2 may be used for all sizes of Raschig rings and Berl saddles. Further experimental work is required to fully establish the effect of high gas rates in all types of packings on the liquid film transfer unit heights.

Column diameter. Examination of the work listed in Table 1 showed no definite effect of column diameter on H_L. These studies included a diameter range of 4 to 20 in. In the absence of further data, it may be concluded that column diameter does not affect H_L.

Liquid properties. The only liquid known to have been used in H_L studies is water; hence the effects of changes in liquid viscosity, density, or surface tension on H_L are not known. Varying water temperatures have been studied but do not provide sufficient information to show the effect of changes in liquid properties as such. Sherwood and Holloway suggested correcting liquid flow rate according to viscosity variations,

Table 1. Experimental studies of liquid film H_L values.

Year	Author(s)	Packing Type	Packing Size, in.	Geometry	Tower Diam., in.	Tower Packed Height, ft.	Solute in Air-Water System	Remarks	Reference
1938	Allen	Raschig rings	½	Round	2.05	1.0	CO_2	Data used by Sherwood and Holloway	1
1940	Sherwood and Holloway	Raschig rings	½ 1 1½ 2	Round	20.0	0.5 to 4.08	CO_2, O_2 and H_2	Gas rate found not to be a variable. Concentration of solute in liquid not a variable. No effect of packed height established. Large decrease of H_L with increasing temperature	13
		Berl saddles	½ 1 1½						
		Spiral tile	3						
1941	Cooper, Christl, and Peery	Steel Raschig rings	2	Square	30.0	7.2	CO_2	Effect of gas recirculation in bed studied	3
1942	Molstad, Abbey, Thompson, and McKinney	Raschig rings	1	Square	15½	2.25	O_2	Excellent agreement with Sherwood and Holloway	11
		Partition tile	3						
		Triple spiral tile	3						
		Berl saddles	1						
		Single spiral tile	3						
1947	Deed, Schutz, and Drew	Raschig rings	½	Round	6	3.92 2.0	O_2 CO_2	Excellent agreement with Sherwood and Holloway	4
1947	Van Krevelin and Hoftijzer	.....	..	....	..	..	..	Analysis of data from numerous sources indicates H_L varies as $Z^{1/2}$	16
1947	Vivian and Whitney	Raschig rings	1.0	Round	4 14	2 4	O_2	Excellent agreement with Sherwood and Holloway	18
1949	Whitney and Vivian	Raschig rings	1.0	Round	8	2	O_2	Excellent agreement with Sherwood and Holloway	19
1949	Koch, et al.	Raschig rings	½ ½ ½ 1½	Round	6-8	4	CO_2	Poor agreement with Sherwood and Holloway	7
1952	Shulman and de Gouff	Raschig rings	1.0	Round	9.72	2	CO_2	Excellent agreement with Sherwood and Holloway	14
1956	Vivian and Peaceman	.....	..	....	..	..	..	Experimental confirmation of basic liquid film theory in wetted wall column	17

but this effect may be included in the Schmidt number correction.

Liquid Schmidt number. Various solute gases have been used in the experimental studies in which the available H_L values have been determined. The liquid Schmidt number, Sc_L, is used to account for differences in the solute diffusion rate characteristics of various systems.

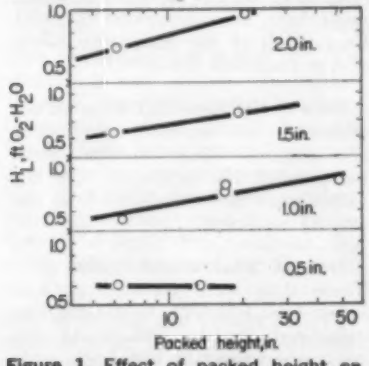

Figure 1. Effect of packed height on H_L for Raschig rings (*13*). $L = 1000$ lb./(hr.)(sq.ft.).

The investigators listed in Table 1 agree that H_L varies as $Sc_L^{1/2}$. Accordingly, values of $H_L/Sc_L^{1/2}$ may be plotted vs. liquid rate L, to obtain a correlation of data taken using any solute gas. Diffusion data from several sources (*2, 5, 6, 8, 9, 12, 15, 17*) were used in this work.

Correlation of H_L data

The data taken from the experimental H_L studies were analyzed by plotting $\phi = H_L/Sc_L^{1/2}$ against liquid rate as in Figure 3.* Values of ϕ were corrected to a common packed height of 10 ft. using the height exponent of 0.15.

The data of Koch *et al.* (*7*) have been omitted because of the poor agreement of their results with all of the other studies. The otherwise excellent agreement of the data from several sources taken with various column diameters, packed heights, and test systems appears to justify

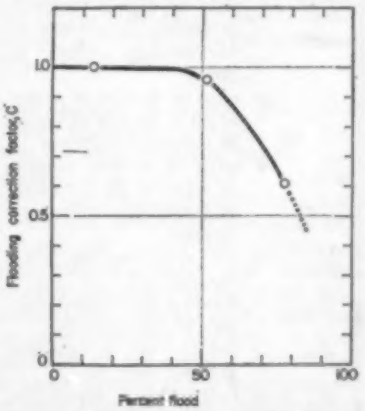

Figure 2. Liquid film correction factor for operation at high percent of flood.

**Plots for other packing sizes (Table 2) may be obtained from the authors.*

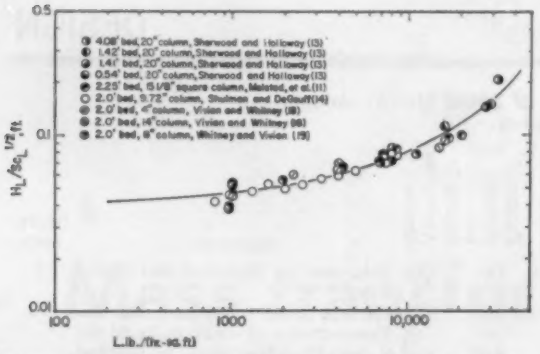

Figure 3. H_L correlation for 1-in. Raschig rings: 10-ft. packed height; less than 50% flooding.

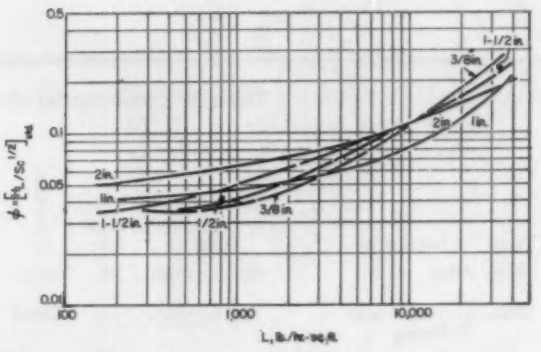

Figure 4. H_L correlation for various size Raschig rings (Table 2): 10-ft. packed height; less than 50% flooding.

the height and Schmidt number corrections as well as to confirm the belief that no diameter correction is involved.

Summary

Final correlation curves for the various sizes of Raschig rings and Berl saddles are given in Figures 4 and 5. The fit of these curves to the original data is shown in Table 2. Agreement is quite good.

For design purposes, values of ϕ are first obtained from Figures 4 or 5. Values of H_L are then found from the following equation:

$$H_L = \phi \cdot (Sc_L)^{1/2} \ (C) \ (Z/10)^{0.15}$$

where H_L and Sc_L refer to the system at hand.

Gas phase mass transfer

This section is a correlation of experimental data in terms of heights of gas film transfer units, H_G.

Previous work

Values of the height of a gas film transfer unit, H_G, must be measured under conditions such that the liquid film resistance is known. This can be done by absorbing a highly soluble gas. The high solubility leads to a low value of m and of the term $(mG/L)H_L$. The resultant small value of liquid film resistance can be used to calculate H_G from H_{OG} data with accuracy.

An alternate method for determining H_G involves vaporization of a liquid at constant temperature into a gas stream. In this case the liquid film resistance is zero, and H_G is the same as H_{OG}. Since the appearance of H_G data by Fellinger *(24)*, much additional work has been published on the heights of gas film transfer units.

Those data of importance in commercial scale design are given in Table 3. Some of the H_G data have been used for establishing the correlations to be presented. Other data, particularly those taken on small columns, were used only in determining the relative effect of packed height, Schmidt number, or column diameter.

Data of Hutchings, Stutzman, and Koch *(28)*. These data required a large liquid film correction. Plots of $1/K_Ga$ vs. $1/G^{0.8}$ at a constant liquid rate were presented. The gas film coefficients were obtained from these $1/K_Ga$ vs. $1/K_G^{0.8}$ plots. This method assumes that there is no effect of percent flood on the liquid film resistance; here the assumption is valid because all of the data were taken at less than 50% flood.

Data of Fellinger *(24)*. Over-all coefficients were reported, and liquid film resistance values calculated from the previous H_L correlation. The H_G values were then calculated from the over-all coefficient.

Data of Houston and Walker *(27)*. These data were reported as K_Ga values from which H_G values could be calculated directly. The liquid film resistance correction had been made using the Sherwood and Holloway correlation *(40)*.

NOTATION

a	= ratio of H_G (maximum) to H_G at any percent flood	H_{OG}	= height of an over-all gas-film transfer unit, ft.
C	= correction factor for H_L at high gas rates	K_G^a	= over-all gas transfer coefficient lb.-moles / (cu. ft.)(atm.)
D	= column diam., in.	L	= liquid mass velocity, lb./(hr.)(sq. ft.)
D_L	= liquid diffusion coefficient, sq. cm./sec.	m	= slope of vapor-liquid equilibrium curve
f_1	= ratio of liquid viscosity at column conditions to viscosity of water at 20°C	Sc_G	= Schmidt number for gas phase, dimensionless
f_2	= ratio of density of water at 20°C to that of liquid at column conditions	Sc_L	= Schmidt number for liquid, dimensionless
f_3	= ratio of surface tension of water at 20°C to that of liquid at column conditions	W	= subscript referring to water
G	= gas mass velocity, lb/(hr.)(sq. ft.)	Z	= packed height, ft.
G_F	= flooding gas mass velocity, lb./(hr.)(sq. ft.)	μ_L	= liquid viscosity, centipoise
H_G	= height of a gas-film transfer unit, ft.	ρ_G	= gas density, lb./cu. ft.
H_L	= height of a liquid-film transfer unit, ft.	ρ_L	= liquid density, lb./cu. ft. or specific gravity as indicated
		σ_L	= liquid surface tension, dyne/cm.
		ϕ	= ordinate value in Figures 3-5 = $H_L/Sc_L^{1/2}$
		ψ	= ordinate value from Figures 9 or 10

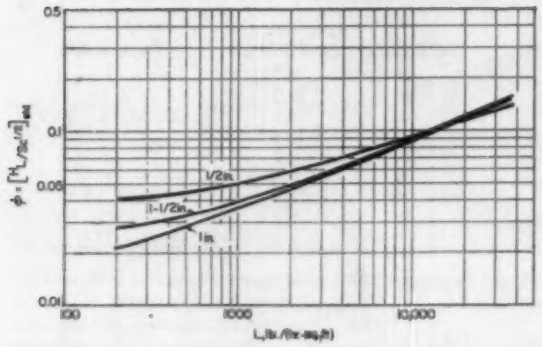

Figure 5. H_L correlation for various size Berl saddles (Table 2): 10-ft. packed height; less than 50% flooding.

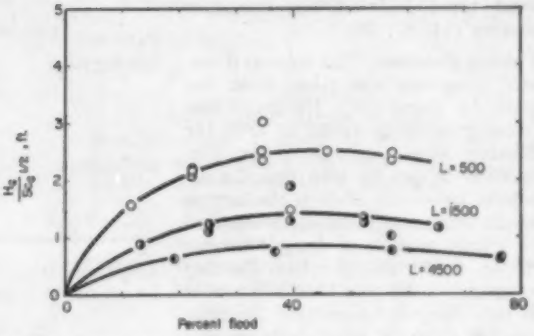

Figure 6. Variation of H_G with gas and liquid rates (24).

Data of Clump (21). The Clump data differ from all others in that they were taken using a packed distillation column and in that they represent the only data for liquids other than water. The system used was toluene/*n*-heptane at the normal boiling point. H_{OG} values were recalculated from the reported bottoms and overhead conditions. The reboiler was assumed to be one theoretical stage.

H_L values were calculated from the previous H_L correlation. Density and viscosity data for the toluene/*n*-heptane system were taken from the literature (38), while liquid diffusion coefficients were calculated by the method of Wilke and Chang (44). Since the data were taken within the composition range in which the equilibrium line is straight, no problem of a variable "*m*" was involved. The liquid film resistance was about one-third of the total resistance in most cases.

Data of Othmer and Scheibel (36). Over-all coefficients were determined and an equation for the liquid film coefficients was reported; from this information H_G values were calculated. Due to the relatively large liquid film resistance, the H_G data scattered somewhat.

Data of Surosky and Dodge (43). Of importance were data for the vaporization of water into air in a one-foot-high packed bed. Other data for shorter beds were analyzed but not used because of the greater end effects. For the one-foot bed, the uncorrected transfer coefficients were used. In the absence of liquid film resistance, H_G values were calculated directly from the data.

Data of Yoshida and Tanaka (46). The constant water temperature data for one-inch Raschig rings were analyzed. H_G values were calculated directly from the data.

Data of Zabban and Dodge (47). Gas film coefficients were reported and H_G values were calculated directly from the data for the condition of no end effect.

Experimental variables study

Variables considered to affect the height of a gas phase transfer unit are: gas velocity, liquid velocity, gas physical properties, column diameter, packed height, packing type, and packing size.

Gas velocity. The importance of gas velocity on the rate of mass transfer in packed beds is well known. Equally well known is the fact that at constant liquid rate, as the gas velocity is increased "loading" and "flooding" conditions are approached. Thus, it is possible to consider gas velocity indirectly as a degree of approach to flooding.

Fellinger (24) clearly illustrated the large variation of H_G in the loading and flooding regions. Lynch and Wilke (31) compared gas film coefficients at equal values of the "flooding modulus", $(L/G)\ (\rho_G/\rho_L)^{1/2}$ in determining exponent values for Schmidt number variations. Zenz (48) related pressure drop characteristics of packed columns to values of "flooding pressure drop".

It was ultimately decided that no better criterion of flooding could be found than the percent of flood itself:

$$\% \text{ flood} = \left[\frac{(G)\ (100)}{G_f}\right]_L = \text{const.}$$

For correlation purposes flooding velocity data given in conjunction with mass transfer data were used whenever possible. In other cases, flooding velocities were taken from charts for air-water (41), or from the generalized correlation of Lobo, Friend, Hashmall, and Zenz (30).

In view of the dependence of the H_G correlations on the percent flood, it can be seen that accurate prediction of the flooding point is just as important as the H_G correlations themselves. Likewise, use of the correlations is predicated on good column design, particularly in regard to proper liquid distribution.

Gas physical properties. For many years the exponent of the gas film Schmidt number was in dispute. Experimental studies listed in Table 3 found values ranging from 0.16 to 1.0. Lynch and Wilke (31) compared H_G values under similar fluid mechanical conditions and found the Schmidt number exponent to be about 0.5. Accordingly, variation of H_G with gas physical properties was taken as proportional to the square root of the Schmidt number at the same percent of flood. Values of the Schmidt number in air were taken from Perry (37); for other systems diffusion coefficients

Fair Cornell Knapp

James R. Fair heads the engineering research section at Monsanto's Dayton plant. A Ph.D., U. of Texas, most of his fourteen years industrial experience has been with Monsanto.

William G. Knapp is group leader, Monsanto's research pilot plant at St. Louis. He has been with the company for ten years.

David Cornell is Associate Professor of Mechanical and Chemical Engineering, Oklahoma State U. He was research chemical engineer at Monsanto's Dayton plant from 1955-58. He is co-author of **Handbook of Natural Gas Engineering.**

were calculated (*23*) and viscosities were taken from various literature sources (*34, 37, 38*).

Column diameter. The column diameter correction was taken from the study by Murch (*35*). He found that packing efficiency varied as $D^{1.24}$ for Raschig rings, and $D^{1.11}$ for Berl saddles. It can be seen that the diameter correction often is the largest single correction factor to be applied in column analysis or design. Examination of the data on 1-in. Raschig rings shows that the Murch exponent is very likely to be correct. No comparable data for large beds of Berl saddles are available. A standard column diameter of one foot was selected as a basis for the correlation. All data were corrected to this standard diameter.

Column height and end effects. Bed heights of 1-20 ft. were included in the studies considered. The Murch exponent of 1/3 for height correction gave very satisfactory results for all the data. A standard height of 10 ft. was used, and all data were corrected to this height.

In most cases where end effects were stated to occur, the authors tested several bed heights and extrapolated to zero height to find the end effect, or to infinite height to find the effective H_G. In all cases, the fact that the coefficient itself varies with height was neglected. In the case of the Hensel and Treybal data (*26*), the end effects were still large due to an efficient distributor. No data for packing heights less than one foot were found to be reliable except in the case of ⅝-in. packing.

Correlation of H_G data

Experimental values of $H_G/Sc_G^{1/2}$ were plotted against percent flood, with parameters of constant liquid rate. A typical plot is shown in Figure 6. It was noted that the curves for a given packing had the same shape and could be brought together by means of a correction factor a:

$$a = \frac{(H_G/Sc_G)^{0.5}}{(H_G/Sc_G)^{0.5}_{max}} = \frac{H_G}{H_{G\,max}}$$

A representative plot of a values is given in Figure 7.

The quantity $H_G/[a(Sc_G^{1/2})]$ is independent of the percent flood and depends upon the liquid rate. Accordingly, plots of this quantity vs. liquid rate were made as shown in Figure 8.* The slope of the plots for Raschig rings was about –0.6 and for Berl saddles was about –0.5. Despite a general scatter of much of the data, which is characteristic of mass transfer data taken from separate sources, a definite correlation for H_G values obtained by absorption, vaporization, and distillation can be seen to exist. To explain the various sources of variability of packed column data the general correlations have assumed a certain degree of complexity. In some cases a threefold variation of H_G occurs. It is hoped that future research will aid in reducing the scatter in mass transfer data and improve our knowledge of this baffling problem.

It might seem unusual that the gas film resistance to mass transfer should depend upon the liquid rate. It should be remembered, however, that the transfer coefficient and the transfer unit contain an interfacial area term. When the liquid rate varies the liquid holdup changes and the change in the interfacial area creates a change in the gas film coefficient. It is of interest to note that the liquid rate exponents agree closely with the exponents obtained from holdup studies (*29, 42*). This link between holdup and the gas film coefficient has been considered previously by Furnas and Bellinger (*25*) and Shulman and coworkers (*42*).

In addition to liquid rate, liquid viscosity, density, and surface tension influence holdup, and hence H_G. Liquid holdup hass been correlated by Jesser and Elgin by the equation

$$\text{Holdup} = b\,L^s \left[\frac{\mu}{\mu_W}\right]^{0.1}\left[\frac{\rho_W}{\rho}\right]^{0.75}\left[\frac{\sigma_W}{\sigma}\right]^n$$

The exponent s varies from 0.51 to 0.58 for Berl saddles, and 0.62 to 0.71 for Raschig rings in holdup work. Considerable doubt as to the value of the surface tension exponent seems to exist, and it is not even certain whether n should be a positive or

Continued on page 74

Table 2. Comparison between predicted and observed values of H_L.

Packing	Size, in.	No. Points	Absolute avg. deviation, %	References
Raschig rings	⅝	10	2.7	1
	½	82	12.2	4, 13
	1	45	8.1	11, 13, 14, 18, 19
	1½	13	10.6	13
	2	15	8.1	13
Berl saddles	½	4	0.8	13
	1	8	8.8	11, 13
	1½	3	7.2	13

* *Plots for other packing sizes (Table 4) may be obtained from the authors.*

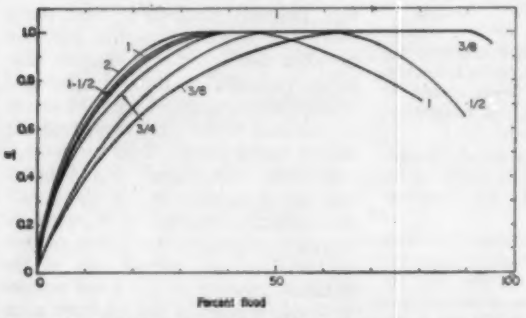

Figure 7. Gas film correction for flooding approach, Raschig rings. $H_G = a(H_{G\max})$.

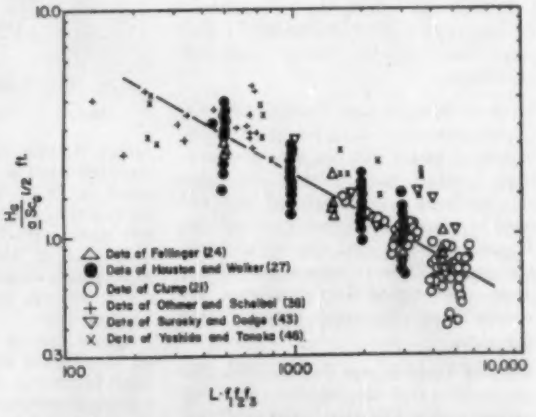

Figure 8. H_G correlation for 1-in. Raschig rings: 10-ft. packed height.

Table 3. Experimental studies of gas film transfer unit height (H_G) values.

		Packing		Tower		Packed Height	System				
Year	Author(s)	Shape	Size in.	Shape	Diam., in.	ft.	Solute	Gas	Liquid	Remarks	Reference
1939	Mehta and Parekh	Raschig rings	½	Round	3.6	0.42	..	Air	Water Methanol Benzene Toluene	Vaporization method. Schmidt number exponent = 0.17 at same liquid and gas rates but different liquids. See Sherwood and Holloway *(40)*	(33)
1940	Sherwood and Holloway	Raschig rings	1	Round	10	1.58 2.58	NH_3	Air	Water	Absorption data of Borden and Squires. Not used.	(40)
		Raschig rings	1	Round	10	1.58 2.58	NH_3	Air	Water	Absorption data of Doherty and Johnson. Not used.	
1941	Fellinger	Raschig rings	½ ¾ 1 1½ 2	Round	18	0.75 1.42 2.13 2.10 1.98	NH_3	Air	Water	Absorption method.	(24)
		Berl saddles	½ 1 1½			1.71 1.83 2.08					
1941	Othmer and Scheibel	Raschig rings	1	Round	9¾	16.3	Acetone	Air	Water	Absorption method.	(36)
1941	Dwyer and Dodge	Raschig rings	½ 1 1½	Round	12	4.0	NH_3	Air	Water	Absorption method. Data not used.	(22)
1944	Scheibel and Othmer	Raschig rings	0.32	Round	4	3.08	4 Ketones	Air	Water	Absorption method. Data not used because of small column diameter.	(39)
1949	McAdams, Pohlenz, and St. John	Raschig rings	1	Round	4	0.5 1.0	..	Air	Water	Vaporization method. Data not used because of small column diameter.	(32)
1949	Hutchings, Stutzman, and Koch	Raschig rings	½ ¾ ½ 1½	Round	6 6 6 10	4.34 4.58 4.56 3.73	Acetone	Air	Water	Absorption method. ½" Raschig ring data not used because of unusually high values.	(28)
1950	Houston and Walker	Raschig rings	1	Round	12	2.0	NH_3 Acetone Methanol Ethanol	Air	Water	Absorption method. Schmidt number exponent = ½ at same liquid and gas rates but with different liquids.	(27)
1950	Surosky and Dodge	Raschig rings	1	Round	8	1.0	..	Air	Water Methanol Benzene Ethyl-n-Butyrate	Vaporization method. Schmidt number exponent = 0.15 at same liquid and gas rates but with different liquids.	(43)
1951	Yoshida and Tanaka	Raschig rings	1	Round	10	1.04	..	Air	Water	Vaporization method. Data on 15 and 35 mm rings not used.	(46)
1952	Hensel and Treybal	Berl saddles	1½	Square	21.5	1.09	..	Air	Water	Vaporization method. Data not used because of large end effects.	(26)
1953	Clump	Raschig rings	1	Round	12	6 10 14 18	.. ..		.. ..	Distillation data on the toluene heptane system.	(21)
1954	Zabban and Dodge	Raschig rings	¼	Round	6	1.83 2.94	Acetone Methanol	Air Air	Water Water	Absorption method.	(47)
		Berl saddles	1	Round	12	4.25 10	Acetone	Air	Water		
1955	Bonilla and Baron	Raschig rings	..	Round	1.1	3.75	Ethylene Oxide	Air Air Air Air Air	Acetone Ethanol Benzene Water Ethyl Aceto Acetate	Data not used because of small column size and mixed packing sizes.	(20)
1955	Lynch and Wilke	Raschig rings	1	Round	12	0.62	..	Air Helium Freon-12	Water Water Water	Data not used because of short bed height. Schmidt number exponent studied.	(31)
1955	Shulman, et al									Attempts to explain differences between studies on the basis of holdup.	(42)
1955	Yoshida	Raschig rings	1	Round	4	0.42 0.62	..	Air		Data not used because of small column size. Schmidt number exponent studied.	(45)

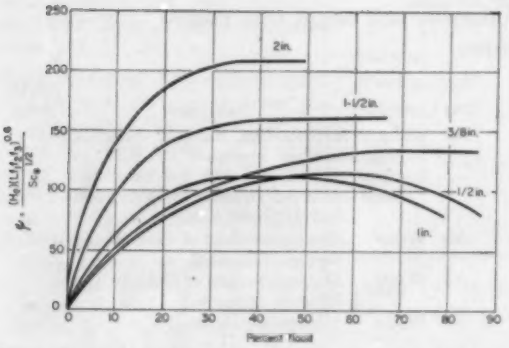

Figure 9. H_G correlation for various size Raschig rings (Table 4): 10-ft. packed height; 1-ft. column diam.

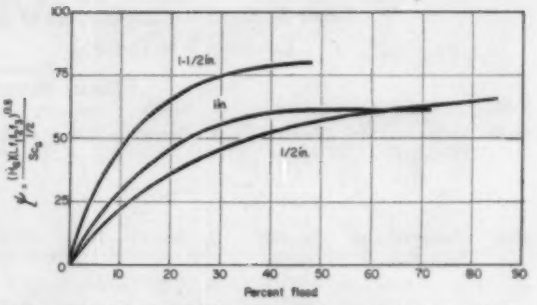

Figure 10. H_G correlation for various size Berl saddles (Table 4); 10-ft. packed height; 1-ft. column diam.

negative quantity. In the absence of definite information at the low liquid rates common to distillation, a value of $n = 0.5$ was taken from Jesser and Elgin (29).

In accordance with the preceding equation, the H_G data plots were made with the term

$$L\left(\frac{\mu}{\mu_W}\right)^{0.16}\left(\frac{\rho_W}{\rho}\right)^{1.25}\left(\frac{\sigma_W}{\sigma}\right)^{0.8} = L\,f_1f_2f_3$$

as the abscissa. The properties of water at 20°C were used as a reference, since most of the data were for this condition. The exponents of the preceding equation were divided by 0.6

Since all of the vaporization and absorption data considered involved water as the liquid phase, the application of the holdup relationship can only be considered as tentative. The surface tension relationship, in particular, is open to question. However, the procedure as given does handle the Clump (*21*) data on distillation satisfactorily, as is shown in Figure 8.

Summary

The information on a values ($a = H_G/H_G$, max.) plus the H_G correlation charts is combined and summarized in the design charts, Figures 9 and 10. Values of ψ are plotted against percent flood for various packing materials. When these design charts are used, fit of predicted to measured H_G data is reasonably good, as shown in Table 4.

For design purposes, values of ψ are first obtained from Figures 9 or 10. Values of H_G are then found from the following equations:

Raschig rings:

$$H_G = \frac{\psi\ Sc_G^{0.5}}{(L\ f_1f_2f_3)^{0.6}}\left(\frac{D}{12}\right)^{1.24}\left(\frac{Z}{10}\right)^{1/3}$$

Berl saddles:

$$H_G = \frac{\psi\ Sc_G^{0.5}}{(L\ f_1f_2f_3)^{0.6}}\left(\frac{D}{12}\right)^{1.11}\left(\frac{Z}{10}\right)^{1/3}$$

where $f_1 = (\mu_L/1.005)^{0.16}$,
$f_2 = (1/\rho_L)^{1.25}$,
$f_3 = (72.8/\sigma)^{0.8}$

and other symbols are defined in the notation.

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Table 4. Comparison between predicted and observed values of H_G.

Packing	Size, in.	No. Points	Absolute Avg. Deviations, %	References
Raschig rings	⅜	47	23.3	*24, 28*
	½	113	32.5	*24, 28, 47*
	1	303	20.7	*21, 24, 27, 36, 43, 46*
	1½	35	18.2	*28*
	1½	12	5.2	*24*
	2	13	8.8	*24*
Berl saddles	½	12	14.8	*24*
	1	51	34.5	*24, 47*
	1½	12	6.8	*24*

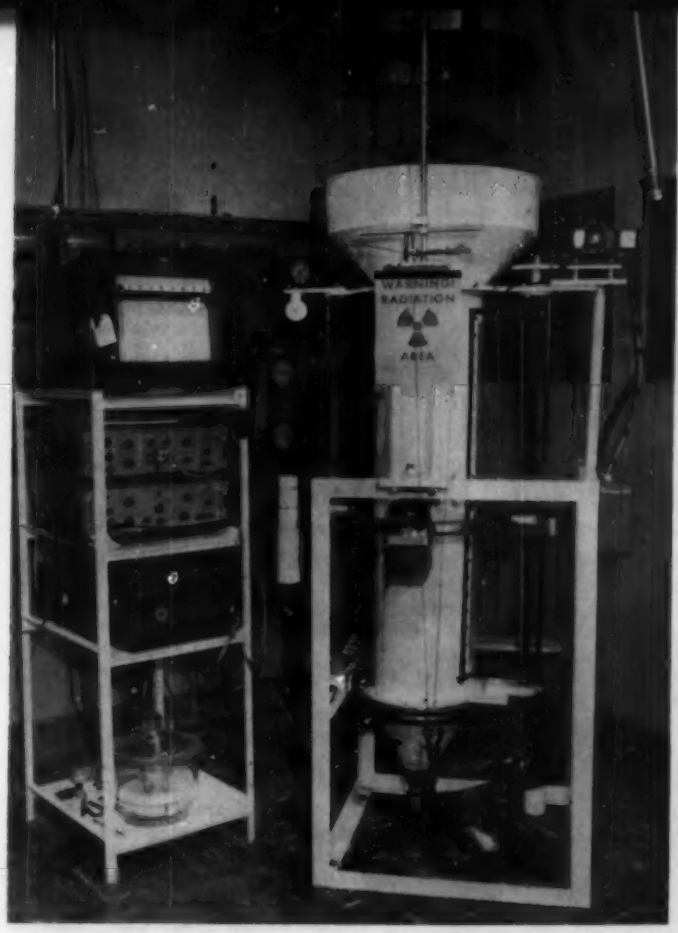

Figure 1. Fluidized bed coating apparatus and auxiliary equipment used by G.E.

JOSEPH GAYNOR
General Electric Company

Fluidized bed coating

Solve your coating problems by the fluidization technique. Use preheat, electrostatic, or adhesive undercoat coating methods.

FLUIDIZED SYSTEMS HAVE BEEN in use for many years although only in the last thirty years has their true potential been realized. The first large scale industrial use of these systems was for catalytic cracking of petroleum crudes. Later it was found that coal could be gasified using a fluidized system.

In the early as well as the more recent investigations, the attractive properties of fluidized systems have been high rates of momentum, heat and mass transfer, and a high degree of versatility. Most recently, investigators have begun to explore more thoroughly new uses for fluidized beds. Such uses as high constant temperature baths, quenching hot gases, production of metals, and many other applications have been reported. The most recent application for fluidized systems is in coating objects with materials which fuse at temperatures below the melting point of the object to be coated.

This new application is an advance in coating technology and represents an opportunity for the chemical engineer to contribute technically to a process area which has sorely needed his help for many years. The classical methods of applying coatings are by dipping, brushing, and spraying. Techniques such as flow coating, electrostatic spraying, electrophoresis, as well as fluidized systems, have slowly begun to replace the older coating methods because they are more efficient, precise, and uniform. These new methods lend themselves to closer control, are more economical, and can be treated as true chemical processes.

Fluidized bed coating process

The fluidized bed coating process is of direct interest to chemical engineers. Within the general framework of this system there are three methods useful in applying coatings. The part to be coated can be heated to some temperature above the melting point of the powder which is being fluidized. When the heated part is dipped into the bed, the particles, which strike the hot surfaces, fuse and adhere. This method is described by Gemmer *(1)*. The preheating step can be avoided by coating the part with a thin tacky coating before dipping into the fluidized bed or by use of electrostatic forces which attract charged particles to the substrate. Where only selected areas are to be coated, the latter two methods tend to minimize masking difficulties.

The advantages which have been claimed for the fluidized process are: no solvents, ability to coat complex geometries, one pass operation, control of coating thickness, efficient utilization of material (theoretically 100%), high coating rate, simple and inexpensive process equipment (Figure 1), easily automated process, smooth continuous coatings, etc. On superficial examination, the process is exceedingly simple and straightforward. However, a thorough analysis of process variables and their possible interaction shows rather quickly that this process is complex. Further it requires a judicious combination of knowledge in two fields — chemical process technology and coating technology. Therefore, it appears worthwhile to discuss in some detail fluidization and coating and to show how these two technologies interact in this new chemical process.

Fluidized coating parameters

Variables such as solids concentration, homogeneity, viscosity, surface tension, interfacial tension, surface conditions, etc., which are important when objects to be coated are dipped into liquids, are also important in the fluidized process. Although surface condition and interfacial tension are important to the success of the process, they pertain to the coating material-substrate relationships rather than to the process.

The relationships for viscosity and surface tension of fluidized systems have been investigated recently by Ohmae and Furukawa (*2, 3*). The viscosity of a fluidized system is related to the resistance encountered when immersing and removing parts. An estimate of the viscosity of a fluidized system can be made by assuming that the shear stress is equal to the pressure drop across the bed only and the shear rate is equal to the linear velocity of the particles and gas. Very low viscosities result from such calculations. These calculations have been checked by actual experiments involving immersion of objects into fluidized systems.

The role of surface tension is abstract. It is related to free energy of the system which should be highly positive. In coating, some of the particles lose their energy; thus, the total energy of the system decreases and results in a small decrease in the free energy of the system. Since this energy loss is small compared with the total energy, the assumption that surface tension is relatively unimportant is probably justified.

The most important quantities which bear on the process are solids concentration and homogeneity. In liquids, the concentration governs in large part the thickness of the coating and the homogeneity controls the uniformity of the coating. The fraction of solids in a fluidized system can be represented by the quantity $(1-\epsilon)$. When multiplied by the true density of the powder, the result is a true solids concentration. The significance of solids concentration in this case is that its value is an index to the concentration of material to which the object immersed in the bed will be exposed. When combined with particle size, the number of particles to which the object is exposed is readily calculated. Both these quantities can then be related to the thickness of the coating which is applied. Furthermore, by comparison of the amount of material available for coating with that which is actually applied, a quantity similar to the well known Langmuir interception parameter can be calculated. Such a quantity would depend on other variables in addition to $(1-\epsilon)$. Gas velocity, particle size, particle size distribution, particle shape, and geometric configuration of the object all play an important role.

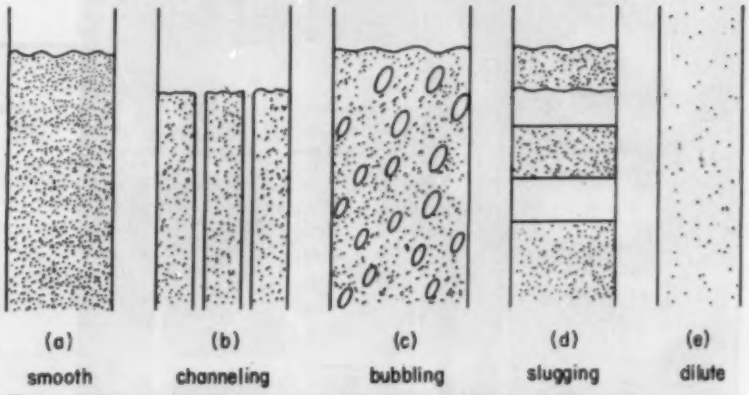

Figure 2. Types of well known flow behavior exhibited by fluidized system.

The quantity $(1-\epsilon)$ can be derived by several methods as follows:

1. From bed expansion measurements, knowing the true density of the solid, the volume occupied by the expanded bed, and the weight of the powder in the bed:

$$(1-\epsilon) = \frac{W}{\rho_s V} \qquad (1)$$

2. From pressure drop measurements utilizing either the Parent, Yagol, Steiner equation (*4*)

$$\Delta p = L(1-\epsilon)\ (\rho_p - \rho_f) \qquad (2)$$

or the Ergun, Orning equation (*5*)

$$\Delta p/L\ g_c = 150\ \frac{(1-\epsilon)^2}{\epsilon^3}\left(\frac{\mu u}{d_p^2}\right) + 1.75\frac{(1-\epsilon)}{\epsilon^3}\left(\frac{G\,u}{d_p}\right) \qquad (3)$$

3. From gamma or x-ray absorption through the bed, the degree of absorption is related to the concentration of solids (*6*) by

$$I = I_o\, e^{-\alpha_M \rho_B l} \qquad (4)$$

$$\rho_B = \rho_S\ (1-\epsilon)$$

$$\ln \frac{I_o}{I} = \alpha_M \rho_S l\ (1-\epsilon) \qquad (5)$$

4. Other techniques which permit determination of $(1-\epsilon)$ at distinct places in the system have also been used. These include a light source and a photoelectric cell, and a capacitometer which measures the capacitance of the gas-solid mixture.

In liquids, homogeneity and uniformity are virtually assured if proper mixing and dissolution procedures have been followed. In fluidized systems neither complete homogeneity nor uniformity is completely possible. The well known kinds of flow behavior exhibited by fluidized systems are shown in Figure 2. Figure 2a

Figure 3. Stages of electrostatic coating of an aluminum rod with Epon resin.

represents ideal behavior, the remainder are commonly encountered phenomena. Since we are dealing with a dynamic rather than a static system, both of the aforementioned properties are intimately linked. If the system is uniform then it will behave alike throughout its volume. That this is rarely the case has been shown by many investigators. Because of boundary effects at the wall, the top surface, and the surface adjacent to the distributor plate, it can be shown that uniformity throughout the volume of a fluidized system is impossible. However it is possible to attain and maintain uniformity over a substantial volume of a bed under certain conditions (*7*). Uniformity appears to depend on height to diameter ratio, particle size, particle size distribution, nature of the distributor plate, and gas flow rate. The effect of these variables on three-dimensional uniformity in fluidized systems has been determined (*7*). The use of nonuniform nonhomogeneous systems results in a nonreproducible process and in nonuniform coatings.

Another factor which arises in the use of fluidized systems, but not in liquids, is the flow disturbance caused by immersing the object in the bed. The shape, volume, and their relation to height and cross section of the bed become important considerations. Thus, for certain applications, fluidized systems of unconventional design may be necessary in order to arrive at an efficient predictable process.

Preheat coating method

Although coating in fluidized systems has been accomplished utilizing three general techniques—preheated part, charged particles or a thin tacky undercoating—the use of preheated parts has received most attention to date. Independent of which technique is used, the particles must melt, flow together, and cover the surface of the substrate. The wetting and flow of polymer melts as they pertain to coating in fluidized systems have been published (*8*).

The use of the preheat method for coating has been well described in the technical literature (*9, 10, 11, 12, 14*) and an extensive discussion here is unnecessary. Time-temperature-coating thickness relations have been determined and preheating methods, as well as techniques for heating *in situ*, have been cited.

The heat transfer phenomena is of interest since one of the advantages of fluidized beds is their high rate of heat transfer. Hot parts might be cooled before they could be coated properly. However, as soon as the heated part is immersed in the system, the particles which strike the surface fuse and adhere. An insulating layer is formed and the heat transfer rate is then limited by thermal conduction through the layer (usually a thermal insulator which is growing in thickness continuously). Simultaneously, heat is being transferred from the surface of the polymer to the fluidized bed. One might conclude that the higher the immersion temperature and the longer the exposure time the thicker the coating. The obvious limitation is that the temperature on the surface of the coating must remain higher than the melting range of the polymer.

Data over large time and temperature ranges indicate that the thickness of the coating is an exponential function of the immersion time and a

Figure 4. Polymethylmethacrylate coating on transformer using tacky undercoat.

linear function of immersion temperature. These data are consistent with related phenomena. The rate of heat transfer is proportional to the temperature difference, thus at higher temperatures more heat is transferred resulting in a thicker coating. It is assumed that the availability of particles is non-limiting. Similarly the cooling curve for objects above room temperature is exponential with time. Thus, it is not surprising that the thickness of the coating is also an exponential function. The asymptote in this latter case is the melting point of the coating material rather than the ambient temperature.

Electrostatic coating

The use of charged particles and electrical fields to coat objects is not new. The Ransburg process in which droplets are charged, sprayed, and attracted to grounded substrates is a well known successful industrial example. The migration of charged particles through a liquid under the influence of an electrical field to a substrate and the use of electrostatic fields to remove charged particles from gas streams are other examples. Therefore, the feasibility of coating by electrostatic techniques in a fluidized system has already been demonstrated. A detailed treatment of the mechanism by which this technique becomes operative is beyond the scope of this survey article. However, a general examination of the mechanisms is presented.

Investigators have reported that fluidized dielectric particles acquire electrical charges. In fact, sparks several feet in length have been observed from an ungrounded column in which a powder was fluidized to a grounded object. Standard practice now requires that all equipment associated with fluidized systems be well grounded, using a single ground. The precise mechanism by which the particles acquire these charges is not clear. The quantity of charge appears to be directly proportional to surface area, air rate, time, and degree of expansion. Humidity decreases charging somewhat, and ionized air reduces charge to zero. It can be shown that fluidized dielectric particles acquire charge even in a grounded column (*15*). Charges as high as several billion electrons/sq. cm./particle have been observed in a fluidized bed. The equation for charge acquired by particles exposed to high potentials has been formulated (*16*) as

$$n = \left(\frac{3\,E_o\,a^2}{e}\right)\left(\frac{t}{t + \dfrac{1}{\pi N_o e_M}}\right) \qquad (6)$$

The particle charge in electrons is proportional to the electric field, the square of the particle diameter, and the time the particle is exposed to the field. The term $1/\pi N_o e_M$ is essentially the particle charging-time constant. The saturation charge approached at large values of t is $3E_o a^2/e$.

To a reasonable approximation the force which opposes electrostatic deposition is given by Stokes' law:

$$F_r = 6\pi\eta a v \qquad (7)$$

Assuming that the piece to be coated is a grounded conductor, the force attracting the charged particle to the conductor is:

$$F_a = \frac{q_p^2}{4r^2} \qquad (8)$$

For dense beds, the surrounding particles may be assumed to act like

planes of charge. Then the attractive force becomes

$$F_{a_1} = \frac{2\pi Q^2}{c_B} \quad (9)$$

If charged conductors or nonconductors are used as substrates, other forces come into play and must be accounted for. Combining Equations 7 and 8, the velocity component in the direction of the immersed part is

$$v = \frac{q_p^2}{24\pi\eta a r^2} \quad (10)$$

Once the particles are attracted to the grounded conducting surface, they are held by electrostatic forces. For simplicity, it is expedient to assume that only the outermost layer of powder behaves as a charged plane. Equation 9 applies and the charge is that on the outermost layer, Q_A. For the actual case, particle to particle charge interaction throughout the volume of particles must be considered as well as the interaction of those particles which are adjacent to the grounded conducting surface. The simplifying assumption does not introduce as large an error as might be presumed at first sight. It can be shown that highly charged particles behave somewhat like conductors. In contact, they will tend to assume an equilibrium energy which is a minimum. This corresponds to charges which reside on the surface alone. During deposition, additional particles are attracted to the layer of powder which has already been deposited by image charges in the substrate due to the charged particles in the bed and by image charges induced in the particles by the charge on the outer layer of powder. This latter attractive force, dielectrophoresis, can be represented mathematically (*17*) as:

$$F_D = c\left(\frac{c_2 - c}{c_2 + 2c}\right)\left(\frac{d_p^3}{8}\right)(E)\left(\frac{\partial E}{\partial r}\right) \quad (11)$$

where $\partial E/\partial r$ is the field gradient at the particle position.

When the part containing the powdered coating is removed from the fluidized system, the force holding the powder on the substrate is given primarily by Equation 9. A specific example will illustrate the relative magnitude of the forces involved and the possible utility of this technique. Assume a charge per particle per sq. cm. of one e.s.u., a dielectric constant of 3.14, a powdered polymer coating bulk specific gravity of 0.5, and a surface area of the part to be coated of one sq. ft. Then, the theoretical thickness of the layer of powder which could be held by electrostatic forces is 40 mils. The coating when fused might be 20 mils thick.

It appears that this technique deserves further exploration. The severity of such problems as masking and corner coverage are materially reduced. Further, it is possible to fuse the coating only, without heating the entire part. The chief drawbacks to the use of this method appear to be the rigid control of process conditions which may be required to permit reproducibility as well as a natural reticence encountered whenever highly charged particles are considered for use in a process. Fig. 3 is a photograph of an aluminum cylinder coated by this technique.

NOTATION

A, B,	= empirical constants	L	= length of the column (ft.)
a	= particle radius (cm.)	l	= length of the path (cm.)
c	= dielectric constant of gas (dimensionless)	M	= ion mobility
c_2	= dielectric constant of particle (dimensionless)	N_o	= ion density in charging zone
d_p	= diam. of particle (ft.)	n	= particle charge (electrons)
E	= field strength between particle and substrate (volts/cm.)	Q	= charge per unit area
E_o	= electric field to which particle is exposed (volts/cm.)	q_p	= charge on particle (e.s.u.)
e	= electronic charge (4.8×10^{-10} e.s.u.)	r	= distance of particle from surface (cm.)
e_M	= electron mobility	t	= time particle exposed to field (sec.)
F_a	= attractive force (dynes)	u	= superficial velocity (ft./sec.)
F_{a_1}	= attractive force (dynes/sq. cm.)	V	= volume of bed (cu. ft.)
F_D	= dielectrophoretic force	v	= velocity of particle cm./sec.
F_r	= retarding force (dynes)	W	= weight of powder in bed
G	= mass velocity (lb./hr.-sq. ft.)	Δp	= pressure drop (lb./sq. ft.)
g_c	= Newton's law conversion factor—lb. mass/lb. force (ft.)/(sec.)^2	$(1-\epsilon)$	= fraction solids (dimensionless)
I	= final intensity of radiation	α	= proportionality constant (ergs/sq. cm.-°K)
I_o	= initial intensity of radiation	α_M	= mass absorption coefficient
		η	= viscosity (gm./cm.-sec.)
		μ	= viscosity (lb./ft.-hr.)
		ρ_B	= bulk density (lb./cu. ft.)
		ρ_f	= density of fluid
		ρ_p	= density of powder
		ρ_s	= true density of solid (lb./cu.ft.)

Thin adhesive undercoat

Perhaps the best evidence to substantiate the utility of this method of coating can be shown by Fig. 4. Here a small transformer was coated with polymethylmethacrylate utilizing a thin tacky coating as a base for the powder. This technique can be of distinct advantage where masking is difficult or if the part to be coated is very large or bulky. A great deal of waste heat can be avoided by fusing only the coating. Paint, spray, and dip techniques are all useful in applying the tacky undercoat. The adhesive can have the same chemical composition as the coating materials, or it can be a plasticizer for the coating, or it can even react with the coating material.

J. Gaynor has published in the fields of adhesion, boundary lubrication, rheology, electrostatic charging in high polymers, fluidization and coating process fundamentals. Now in the Materials Engineering Laboratory, General Electric, he joined the Schenectady firm in 1955. Gaynor attended Brooklyn Polytechnic Institute, and Case Institute, where he received an M.S. and Ph.D.

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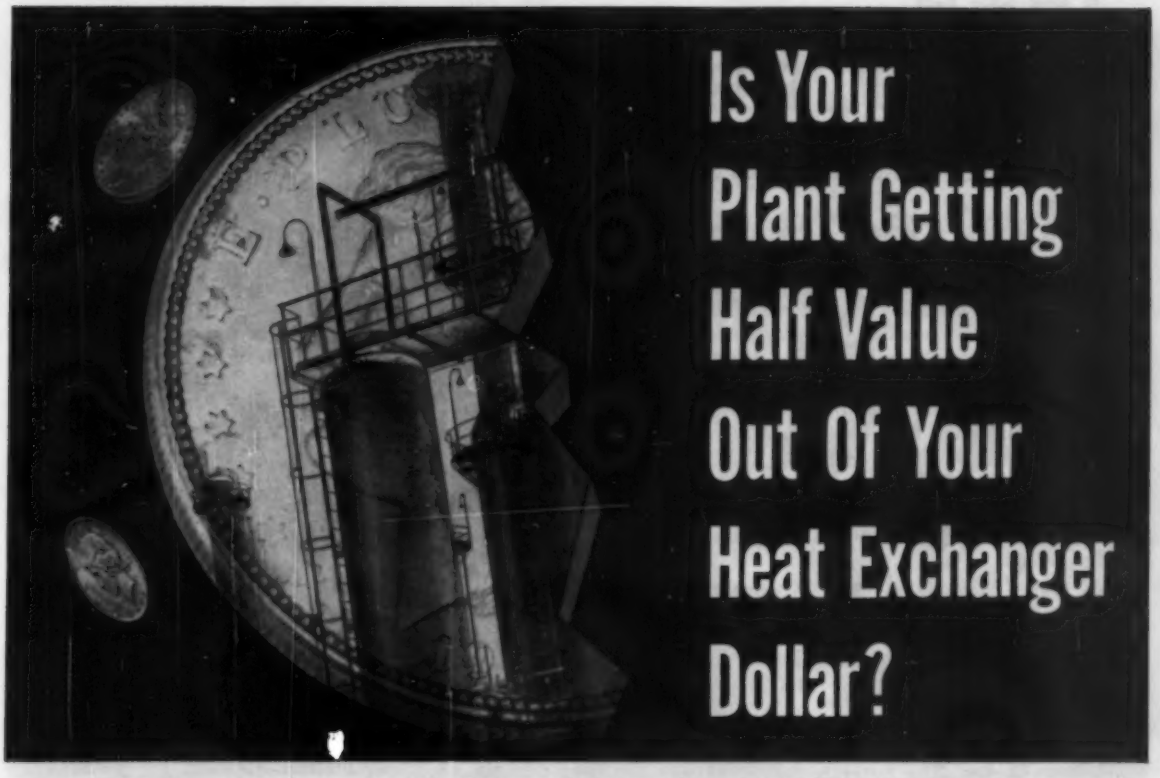

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COMPUTER PROGRAM abstracts

The Machine Computation Committee of the A.I.Ch.E. is interested in receiving program abstracts for publication as part of its program interchange activity. Details of this activity are given in the *Guide to Abstracts and Manuals for Computer Program Interchange*, which has just been revised based on experience during the first year the interchange has been functioning. Copies of the new *Guide* are available at no cost from the A.I.Ch.E. in New York.

Once again the Committee wishes to emphasize the three rules for participation in the interchange program:

1) Abstracts submitted for publication must follow the form shown in the *Guide*.

2) The submitter of the abstract agrees to make available for publication a program manual, prepared as described in the *Guide*, should sufficient interest develop.

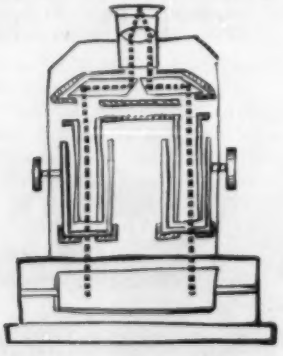
3) Abstracts for publication, and all questions concerning published abstracts, must be sent to the Machine Computation Committee c/o A.I.Ch.E.

Two manuals are now available: *Line Sizing* and *Liquid-Liquid Heat Exchanger Design*. The latter is described on page 161. Scheduled for completion before the end of the year are manuals on *Multicomponent Distillation (Abstract 020)*, *Nonlinear Estimation (016)*, *Piping Flexibility (002)*, *and Plate-to-Plate Distillation Procedure (017)*.

Color properties from Bausch and Lomb Spectronic 20 colorimeter data (036).

William I. Martin
Koppers Company, Inc.
Verona Research Center
Box 128, Verona, Pennsylvania

Description: The program uses the measurements of percent reflectance at ten wave lengths of either a pigmented or unpigmented plastic sample



obtained on a Bausch and Lomb Spectronic 20 Colorimeter. It calculates yellowness and brightness of a sample following procedures in Instrument Development Laboratories, Inc., Color Eye Manual, and B. and L. Color Analyzer Reflectance Attachment for Spectronic 20 Colorimeter Manual. The program also calculates x and y chromaticity diagram coordinates, luminance, dominant wave length and percent purity using methods described in ASTM Methods D 307-44, D 791-54 and the basic formulas also given in *Science of Color* by the Committee on Colorimetry of the Optical Society of America.

Computer: IBM 650 basic
Language: SOAP
Running Time: One hundred calculations in under five minutes or 750 calculations in fifteen minutes.
Availability: A manual could be prepared if sufficient demand develops.

Equilibrium constants from the Benedict-Webb-Rubin equation of state (044).

D. J. Hartline
Design Engineering Division
Esso Research & Engineering Co.
P. O. Box 209, Madison, New Jersey

Description: This program will calculate the vapor-liquid equilibrium constants for any mixture of methane, ethylene, ethane, propylene, propane, isobutane, isobutylene, normal butane, isopentane, pentane, normal hexane, and normal heptane. It is limited to these twelve components, for which Benedict-Webb-Rubin equation constants are available.

Benedict, Webb, and Rubin

$$P = RTd_m + \left(B_oRT - A_o - \frac{C_o}{T^2}\right)d_m^2 + \left(bRT - a\right)d_m^3 + a\alpha d_m^6 + \frac{cd_m^3\left(1+\gamma d_m^2\right)}{T^2}e^{-\gamma d_m^2}$$

The input data required are temperature, pressure, and the approximate mole fraction of each component in both liquid and vapor. The programs will calculate and print out equilibrium constants for practically any temperature, pressure and combination of mole fractions submitted, whether they have any physical significance or not.

Computer: IBM 704, 4,000 words core memory or larger.
Program language: Fortran I.
Running time: Approximately one-half minute to read in the program on cards then 10-15 seconds per problem.
Availability: The manual on this program can be made available for publication should interest develop.

Selective curve set (053).

J. R. Walker
Celanese Chemical Company
Data Processing System
P. O. Box 561
Corpus Christi, Texas

Description: Given a set of x-y data, this program calculates the coefficients for thirty-six simple, arbitrarily selected empirical equations. Three aditional quantities are calculated for each equation to help determine the quality of the fit.

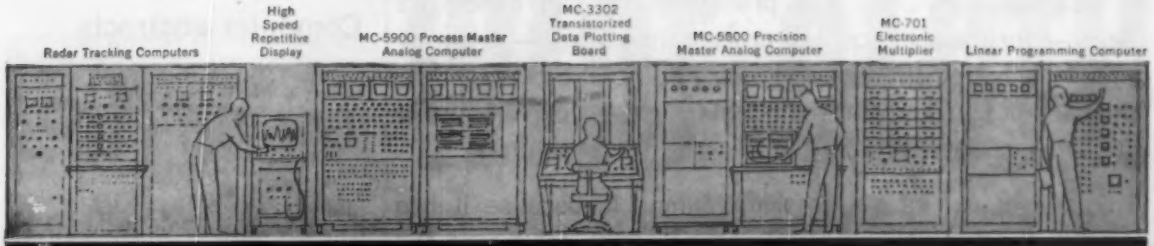
The thirty-six equations are obtained by analyzing the dependent variable y for a relationship to the independent variable x as:

$$y = m\,\phi\,(x) + B$$

$$\frac{1}{y = m\,\phi\,(x) + B}$$

$$y = 10^{\,m\,\phi\,(x)\,+\,B}$$

continued on page 82



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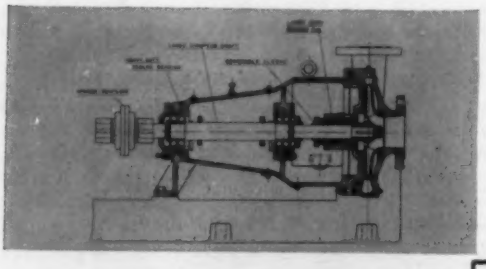

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Computer abstracts

from page 80

where ϕ (x) is sequentially:

x
$1/x$
$\log x$
e^x
x^2
$1/x^2$
$x \log x$
$(1 + x)x^2$
$(1 - x)x^2$
$\log x/x$
$(1 + x)^2$
$(1 - x)^2$

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maximum absolute deviation that occurs in the data set, and the position of the maximum deviation are reported for each equation.

Computer: Burroughs 205; paper tape input-output.

Program language: Burroughs 205 machine code.

Running time: The running time is dependent on the number of data points used. A sample run containing 16 points (32 x-y values) required approximately one minute per equation including punch-out of the calculated coefficients and constants along with the alphabetic equivalent of each equation.

Availability: A manual will be prepared if sufficient interest in this program develops.

An expansion in facilities at Goodyear's vinyl resins plant at Niagara Falls, N. Y., will double capacity for two specialty dispersion resins—Pliovic WO and Pliovic AO. The $1 million addition will add about 20 million pounds annually to total plant output. Part of the company's overall $90 million capital expenditure program for the year, it is expected to be in production by late this year.

Modernization of methyl chloride, methylene chloride and chloroform production facilities at the Belle, W. Va., plant of Diamond Alkali Chlorinated Products Division, are part of a long range expansion program. Construction will start shortly.

Plans to triple production of isocyanates at Allied Chemical's Moundsville, West Va., plant are underway. New construction will be done in stages, is due to be completed in mid 1961.

Lithium compounds will be promoted and sold in the United States under an agreement between U.S. Borax and Lithium Corp., making U.S. Borax sales agent. The agreement covers the sale of lithium compounds used by the ceramic and glass industries, as well as joint development and promotion of other industrial uses for lithium.

Nylon tire cord monofilament and molding compounds will be manufactured by a new company, Allied Polymer Pty. Ltd., Australia. Jointly owned by Allied Chemical and Polymer Corp., initial capacity of the firm is sufficient for all current needs of the Australian market. Pending start-up of the Australian facilities, Polymer will market the Plaskon nylon molding compound manufactured in Virginia.

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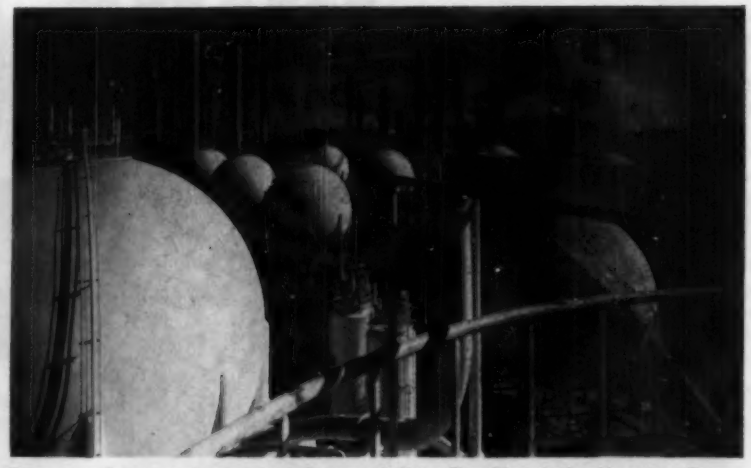
industrial news

More maleic from new process

Butylene oxidation process is low cost, higher yield, says Petro-Tex. New Houston unit marks entry into maleic anhydride.



Storage spheres and process columns at Petro-Tex Chemicals, Houston, Texas, complex, where maleic anhydride unit using new butylene oxidation process is under construction.

A NEW MALEIC ANHYDRIDE production process, using low cost C_4 hydrocarbons as a starting raw material, bolsters another entry into the commercial maleic picture. Petro-Tex Chemical is building one of the largest maleic units ever engineered at one time within its plant complex at Houston, Texas: 30 million pounds annual capacity.

Advantage of its new butylene oxidation process, the company says, is the straightforward oxidation of four-carbon feedstock to produce the maleic. This is an improvement, they say, over the six-carbon benzene which inherently loses one-third of the feedstock. Maximum theoretical yields of maleic from benzene are limited by the loss of two carbon atoms when the six member ring is split to form the four carbon dibasic acid anhydride. While earlier attempts to make maleic from butylene and butadiene were unsuccessful, Petro-Tex says that its process manages to achieve yields higher than those obtained from benzene. And there is considerable room for further improvement in yields and costs, it claims.

The new process has the advantage of lower unit cost for its raw materials since the multi-million dollar facility will use the feedstock streams, utilities, and services of the Houston complex. Thus it will take advantage of the high volume production of four-carbon feedstocks at the unit.

Engineering for the facility will be done by Scientific Design, engineers of a good percentage of the world's maleic capacity, all by the conventional benzene method. Some of the SD processing know-how will be used in areas outside of the oxidation step.

Major factor in Petro-Tex' decision to enter the field right now is not only continuing growth of the market, but also the fact that older and more obsolescent facilities may not be able to supply needs on a competitive basis.

Comparison of methane versus liquid petroleum fractions in the manufacture of carbon disulfide.

BASIS: One Pass through Converter

Methane Process: $CH_4 + 4.4S = .75CS_2 + .25CH_4 + 1.5H_2S + 1.4S$

Fuel Oil Process:

Fuel Oil $CH_{1.4} + 2.97S = CS_2 + .7H_2S + 0.27S$

Heavy Residuum $CH + 2.75S = CS_2 + .5H_2S + 0.25S$

(Approximate Values)

PROCESS	Methane	Petroleum Liquid	
FEED:	Methane	Gas Oil	Heavy Residuum
Empirical Formula	CH_4	$CH_{1.4}$	CH
Feed Needs Purification Before Use	Yes	No	No
Economical Transportation Other Than By Pipe Line	No	Yes	Yes
Assumed Conversion per Pass	75%	100%	100%
SULFUR (lbs/Ton CS_2 Produced):			
To Vaporize & Superheat	4940	2501	2316
To Recycle:			
From sulfur feed	1572	227	211
From H_2S oxidation	1684	589	421
Total	3256	816	632
RECOVERY & PURIFICATION (After sulfur removal from reacted gases):			
Moles CS_2 per 100 moles reacted gases	30	41	67
Moles gases to condenser per ton CS_2 produced	88	45	39

New carbon disulfide process

Liquid petroleum fractions manufacturing method ready for pilot plant development, international significance seen.

A NEW PROCESS which employs liquid petroleum fractions instead of conventional methane gas in carbon disulfide production has been made available for pilot plant development by interested companies. While full details are not released, it is known that the process produces a higher yield of carbon disulfide with less by-products, and requires less handling and heating of sulfur per ton of carbon disulfide produced. Using heavy residuum, it makes more than twice as many moles of carbon disulfide per hundred moles of reacted gases. As a result, recovery equipment and re-

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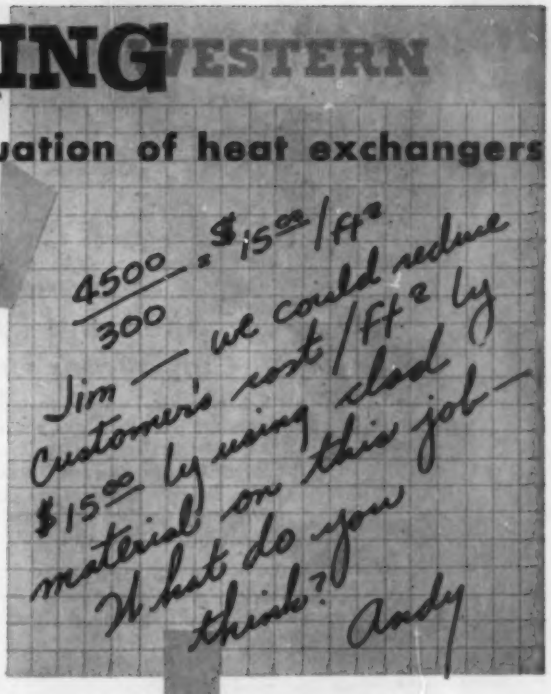
COST ENGINEERING

is the key to economic evaluation of heat exchangers



Recognizing the importance of accurate economic evaluation of capital equipment to our customers' profit structures, Western's engineers have for many years applied cost-engineering principles to the design and fabrication of all Western Heat Exchangers.

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. . . is in the young engineers who are interested in the specialty of "cost-engineering" in heat transfer economics. To stimulate such thought, another of Western's "personal-professional-advancement" messages, partially shown at right, currently appears in several trade journals. A more complete treatment of the subject is available in pamphlet form, singly or in quantity, upon request.

One of a series appearing in OIL & GAS JOURNAL, CHEMICAL ENGINEERING, PETROLEUM REFINER, REFINING ENGINEER, CHEMICAL ENGINEERING PROGRESS.

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For more information, turn to Data Service card, circle No. 2

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Disulfide process

from page 84

frigeration requirements are much less than for the methane process.

The liquid petroleum process is called "revolutionary" by its creator, Carlisle M. Thacker, technical director of Taylor Fibre Co., Norristown, Pa. He says that it is more economical than the methane process, which he also developed, and the multiple-retort process. Estimates on cost are that the process will need about 25 percent less in plant investment and 15 percent less in production costs than the others.

Low cost fractions are most suitable for this process: gas oils, fuel oils, and petroleum residuums, particularly petroleum liquids, containing high concentrations of sulfur. These are much cheaper than the natural gases from which methane is obtained.

The process also makes feasible the installation of production facilities in countries where degree of industrialization is varied, because the capacity of the facility can be determined by demand for carbon disulfide in the manufacturer's trading area. An important advantage over methane would be greater flexibility in transporting. Since methane can be transported economically in large volume only through gas pipe lines, plants using methane gas must be located either at methane gas producing centers or along gas pipe lines. This rules out the use of methane in many countries, as well as in many areas of the United States. Liquid petroleum fractions can be transported economically by pipelines, sea going tankers, tank cars and tank trucks.

Thacker predicts that carbon disulfide plants will help meet the demand for increased amounts of the solvent for rayon, cellophane and carbon tetrachloride production, particularly where low volume production is required as in captive plants of carbon disulfide users.

Construction of a chemical complex to convert hydrocarbons is planned by The Borden Co. and U.S. Rubber. A new jointly owned company, Monochem, has optioned several plant sites. Capacity will be more than 80 million pounds of acetylene and 150 million of vinyl chloride monomer annually. Major initial use would be by Borden, in the manufacture of vinyl plastic resins. Both plants will erect adjacent individually owned plants which will use the output of Monochem for manufacture of other chemical products.

For more information, circle No. 119

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U.S.I. CHEMICAL NEWS

July ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1960

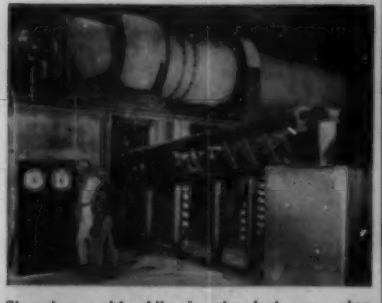
60% Interest in Mallory-Sharon Metals Acquired By National Distillers

New Name—Reactive Metals, Inc.

National Distillers, formerly one-third owner of Mallory-Sharon Metals Corporation, has recently acquired a 60% interest in the company. The operations of Mallory-Sharon Metals are being integrated with those of its now 100%-owned subsidiary, Johnston & Funk Metallurgical Corp., and the combined company is to be known as Reactive Metals, Inc. Sharon Steel Corp. owns 40% interest in Reactive Metals.

This reorganization will make Reactive Metals one of the world's largest producers of special metals such as zirconium and titanium sponge and mill products, and columbium, hafnium, molybde-

MORE



Zirconium oxide kiln in chemical processing section of Reactive Metals zirconium sponge plant at Ashtabula, Ohio.

Corrosion Costs Slashed by Large-Scale Titanium Use

Two ore processing units, completed in the past year, are the first Chemical Process Industry installations to make extensive use of titanium equipment in highly corrosive service. The decision to use titanium was based on 15 months of pilot plant studies in which the higher-priced metal proved most economical in terms of equipment life expectancy.

Titanium was tested against stainless steels, Hastalloys, Monel, other alloys and nonmetallics, for leaching reactors and piping to handle mixed ore and 10% sulfuric acid and for oxidation autoclaves and piping subject to dilute acid, all at high temperatures and pressures. Titanium showed almost no corrosion, came out first among all the materials tested.

As a result of these

MORE

Production of Nonfood Aerosol Units Estimated at 575 Million In 1959, C.S.M.A. Reports

1959 Figure Represents 22% Increase Over 1958. Hair Sprays Lead for Forth Year, but the Figure Is Down From 1958

On May 18, at the annual meeting of the Chemical Specialties Manufacturers Association in Chicago, it was revealed that an estimated 575 million nonfood aerosol units were produced in 1959. This represents a growth of 22% over 1958, when 470 million units were estimated. The retail value of these units in 1959 was about ¾ of a billion dollars.

The CSMA figure is based on reports from container and valve makers and on responses from 58% (115 out of 198) of the known aerosol fillers—adjusted to account for nonreporting fillers. The actual number of units reported for the year was 498 million.

How the Major Products Ranked

For the fourth year now, hair sprays topped the list, and accounted for 16% of the total units reported. Shaving lathers moved up from third to second place to claim 15% of total production. Insect sprays advanced from fourth to third spot with 13%. Room deodorants, formerly second, ranked fourth with 12%. Coatings remained in fifth position with 11%.

NONFOOD AEROSOLS REPORTED IN 1959 COMPARED TO 1958

(figures in millions of units)

Product	1959	1958
Hair Sprays	76.7	92.6
Shaving Lathers	72.6	45.3
Insect Sprays	65.9	42.3
Room Deodorants	59.7	49.8
Coatings	52.6	30.1
Colognes & Perfumes	34.1	13.6
Glass Cleaners	18.5	3.7
Household Products Other than Room Deodorants and Glass Cleaners	59.1	22.2
Personal Products Other than Hair Sprays, Shaves, Colognes & Perfumes	33.5	27.4
Miscellaneous	22.6	14.4
TOTALS	498.3	341.4

It is to be noted that aerosol cologne and perfume production went up from 14 to 34 million reported units in 1959. And that containers under one ounce accounted for 17% of the perfume and cologne units reported for the year. A separate category for Waxes and Polishes was set up under Household Products in 1959, and revealed a total of 12 million

MORE

Methionine Needs Reported Higher in Men Over Sixty

In a study reported recently, methionine requirements of men over 60 were determined by the nitrogen balance technique. It was discovered that they needed from 2.4 to 3.0 grams of methionine per day—more than twice the amount of 1.1 grams reported necessary for young men.

Nitrogen equilibrium was established for a group of men over sixty fed a diet of ordinary food with known nitrogen content. With the information thus obtained, a semi-synthetic diet was given them which contained the same amount of total nitrogen. This diet furnished all essential and non-essential amino acids in the ratio found in egg protein.

This second diet included three grams of methionine per day. The methionine level was gradually reduced until a negative nitrogen balance was obtained. Control and test diets were alternated until the methionine needs of the men were determined accurately.

U.S.I. Announces Booklet On Polyethylene Printing

"Printing of Polyethylene" is the title of a new U.S.I. booklet now available. It's the latest addition to special U.S.I. literature designed to help achieve finest results with polyethylene film.

The new booklet discusses methods of film treatment, printing techniques, printing inks and field test procedures. It also contains a glossary of commonly-used ink and printing terms.

A copy of the 16-page booklet can be obtained by writing to the Technical Literature Department, U.S.I. Chemical News, 99 Park Avenue, New York 16, New York.

July ★ **U.S.I. CHEMICAL NEWS** ★ 1960

CONTINUED *Aerosols*

units for the year. Also for the first time, a separate figure for Canadian aerosol production was included—a total of 20 million units from eight Canadian producers. These figures are included in the overall survey for continuity purposes.

U.S.I. Products Used in Aerosols

U.S.I. products, ethyl alcohol and polyethylene, are playing an important role in the large and steady growth of the aerosol industry. Anhydrous ethyl alcohol is a vital ingredient in the top-ranking products—hair sprays and room deodorants—and in the growth leaders—perfumes and colognes. It is widely used in other personal products, and in pharmaceuticals now sold in aerosol form. Polyethylene is used for dip tubes and valve parts.

Last year we reported a forecast by one of the largest makers of aerosol containers —that total production of aerosols would reach 555 million units in 1959. It looks as if the prediction wasn't optimistic enough. Let's see what 1960 brings!

CONTINUED *Reactive Metals*

num, tantalum, tungsten and vanadium mill products. With total assets of over $50,000,000, the company plans to continue emphasizing the production of a wide variety of special metals so that it will be in a position to expand its interest in one or all of them as markets develop.

The contract under which Brideport Brass Company has been managing Mallory-Sharon Metals will be revised to cover Reactive Metals. Executive offices of Reactive Metals will be located at Bridgeport, Conn. Titanium and zirconium sponge division headquarters are at Ashtabula, O.; columbium, molybdenum and tantalum mill products division at Huntsville, Ala.; titanium, zirconium and special steel mill shapes division at Niles, O.

CONTINUED *Titanium*

studies, titanium was employed as follows: In leaching reactors, overflow pipes were lined with titanium; reactor draft tubes, nozzle inserts, and pipe lines connecting reactors, slurry heaters, slurry coolers and flash tanks, were made of titanium. In autoclaves, titanium was used for agitator shafts and blades, autoclave nozzles, connecting piping including letdown valves.

To cut costs, engineers made exact calculations of metal thicknesses required, figured sizes and lengths of pipe as precisely as possible, carefully arranged equipment layouts. In design and production, many basic problems of titanium fabrication were successfully solved, and many economic considerations worked through. Other companies in the process industries can now apply the considerable knowledge gained on this project to utilize the vast potentials of titanium as a corrosion-resistant material.

New U.S.I. Ethyl Acetate Data Sheet Now Available

Three grades of ethyl acetate are described in a new technical data bulletin just released by U.S.I. The grades are: commercial 85-88% ester; 95-98% ester; and 99% ester (acetic ether). Data include U.S.I. specifications, properties, shipping information and uses.

Ethyl acetate is the standard fast-evaporating solvent for nitrocellulose. It is used as a solvent to process or produce lacquer, varnish, smokeless powder, photographic film, pharmaceuticals, perfumes, textiles, plastics, coatings, cleaners and many other products. It is also a chemical intermediate for the manufacture of ethyl acetoacetate and ethyl sodium oxalacetate.

For a copy of the new data sheet, contact your nearest U.S.I. sales office or Technical Literature Dept., U.S.I. Chemical News, 99 Park Ave., N. Y. 16, N. Y.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

New compound, said to lower elevated blood cholesterol levels dramatically with virtually no side effects, is now on market. No dietary restrictions necessary. Contains aluminum nicotinate which hydrolyzes in body. **No. 1610**

Benzotrifluoride and its ortho-, meta-, and para-chloro isomers now available on commercial scale. Suggested uses include manufacture of diuretics and tranquilizers, dyestuffs, biocides, dielectric fluids. **No. 1611**

Stabilized formaldehyde solutions now available are said to permit safe storage at temperatures well below previously recommended levels. Minimum for 37% solution (1% methanol) has been reduced from 90 F to 60 F. **No. 1612**

Tritiated L-histidine, new radioactive material for biochemical tracer studies, now available. Since D-form is absent, this pure tritiated L-amino acid is said to eliminate background interference in radioautographs. **No. 1613**

Special circular slide rule for solving atomic fallout problems is being sold. Quickly tells what radiation level will be anytime after an area experiences atomic fallout from atomic bomb or similar nuclear occurrences. **No. 1614**

Pure crystalline xanthopterin now being offered. Sale to extend possible application of compound in research on purine and nucleic acid metabolism in normal and neoplastic cells. **No. 1615**

Activated charcoal paint now available can be coated on any surface to give odor adsorptive properties to rooms, containers, fabrics, etc. Can be removed by water scrubbing after decontamination operations, it is claimed. **No. 1616**

For determination of arsenic in parts/billion amounts, stable reagent grade of silver diethyldithiocarbamate has been developed. With arsine, forms soluble red complex whose absorbance is proportional to concentration of arsenic over wide range and is easily measured. **No. 1617**

Two new radioactive carbon compounds, cortisone-4-C^{14} and cortisone-4-C^{14} acetate, now on market. These anti-inflammatory, anti-allergic, anti-fibroplastic agents are used in adrenal cortical insufficiency studies. **No. 1618**

All existing information on sodium chloride has been compiled for the first time in a new, 752-page monograph now being sold. Brings together all modern data on salt sources, production, properties, uses. **No. 1619**

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industrial news

MCA opposes "per se" cancer clause

THE "PER SE" PROHIBITION against possible cancer producing substances in food, contained in the Food Additives Amendment to the Food, Drug and Cosmetic Act, should be eliminated as unnecessary, the Manufacturing Chemist's Association believes. Adding its voice to the current discussion on the use of chemicals in food, and on the amendment which went into effect in its entirety in March, the Association stated that as an alternative, the clause should be modified to substitute scientific evidence for legislative fiat in evaluating the safety of such substances. MCA's views were expressed by James M. Gillet before the one-day session on food additives held before the Wisconsin Legislative Council Agricultural Committee at Madison, Wisconsin, in March.

A similar cancer clause in the Color Additives Bill pending in the House, in MCA's view, also bars the consideration of scientific evidence in evaluating such substances.

The Food Additives Amendment provided that any substance not recognized by experts as safe under the conditions of its intended use, or which has not been sanctioned under existing laws, which is proposed for use so that it may either become part of the food, or affect its quality, must first be proved to be safe for its intended use. (This applies to interstate commerce.) Clearance of new food additives can be obtained only after the Commissioner of Food and Drugs has issued a regulation announcing the conditions under which safe use has been established.

Later, the "per se" provision was added to the bill. This applies against any substance that could conceivably cause cancer under any conditions, no matter how remotely connected with the conditions of intended use. The 1906 original Pure Food Law similarly provides that any poisonous substance which might render the food or animal feed injurious to health could not be added. Thus, Gillet said, a substance which when added would save the farmer, the processor and the consumer large sums of money in the prevention of spoilage, was illegal even though the consumer would need several thousand pounds of food at one sitting to ingest a minimum dose.

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industrial focus

J. M. Dale & R. C. DeHart,
Southwest Research Institute

Nuclear fire and brimstone

Technical evaluation and preliminary cost estimates indicate feasibility of using underground nuclear blasts to exploit Frasch-type sulfur deposits.

Results obtained under the AEC Plowshare Program have shown that nuclear detonations may be completely contained under ground. This has prompted a consideration of the technical and economic feasibility of using underground nuclear explosions for mining sulfur. The nature of Frasch-type sulfur deposits, together with the relatively low melting point of sulfur, appears to lend itself readily to such an undertaking.

The Frasch or salt-dome type deposits are characterized by a barren anhydrite or gypsum layer across the top of the dome. Above this occurs the cavernous sulfur-bearing limestone. Still higher up is a barren limestone cap rock which is covered by various unconsolidated sedimentary deposits extending up to the surface. Productive cap rocks occur at depths ranging from 500 to 2,000 feet. The barren cap rock varies in thickness from 5 to 200 feet. The sulfur-bearing formation varies from 25 to 350 feet in thickness, and generally contains between 20 to 40% sulfur by volume. The anhydrite layer generally varies in thickness from 50 to 400 feet. Below this, rock salt exists down to an unknown depth. (Only about 5% of the salt domes have proven to have sulfur-bearing cap rocks).

Nevada test sites

Results of core drilling at the test sites used by AEC in Nevada seem to indicate the following sequence of events. At the moment of the explosion, a cavity is produced and its walls are heated to several thousand degrees Centigrade. The size of this cavity and the resulting stresses and temperatures in the soil can be predetermined from certain basic data. The cavity is surrounded by a shell of fused material which exists a sufficiently long time for droplets and icicles to fall from the roof. The top half of the cavity soon begins to collapse, and progressive caving takes place above the center of the cavity forming a chimney.

Conservation of energy

In the explosion of a conventional high-explosive bomb, nearly all of the energy released appears immediately in the form of blast energy. In a nuclear explosion, however, about 50% of the total energy is utilized to cause blast and shock, with 35% going into thermal radiation. Thus, much higher soil temperatures can be produced by nuclear explosives than by conventional explosions.

Because of the self-insulating properties of solid sulfur, the heat liberated by a nuclear explosion set off in the sulfur-bearing formation (Figure 1) would be an effective way to trap and retain the heat. Molten sulfur running out of cracks and fissures would soon fall below its freezing point of 238°F, and these escape paths would be blocked. Sulfur has an unusual viscosity curve in that, above 320°F, its viscosity increases rapidly, making it difficult to handle. Above 375°F, the viscosity curve decreases up to the boiling point of 832°F. In view of this, production from a blast directly in the sulfur formation should be attempted immediately after detonation, or a sufficient time should be

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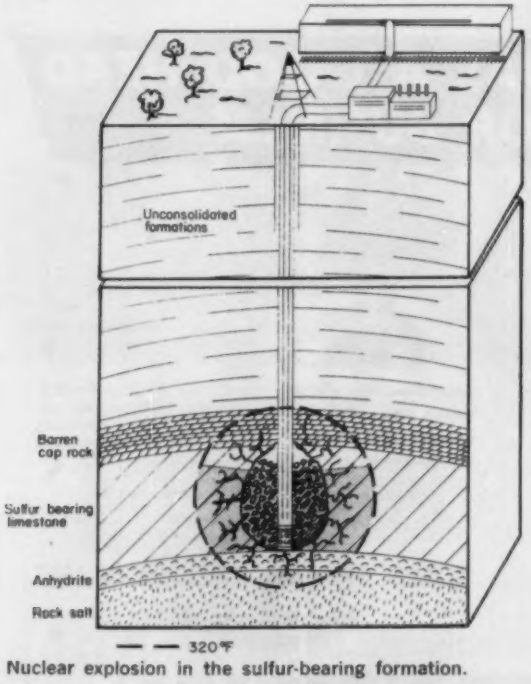
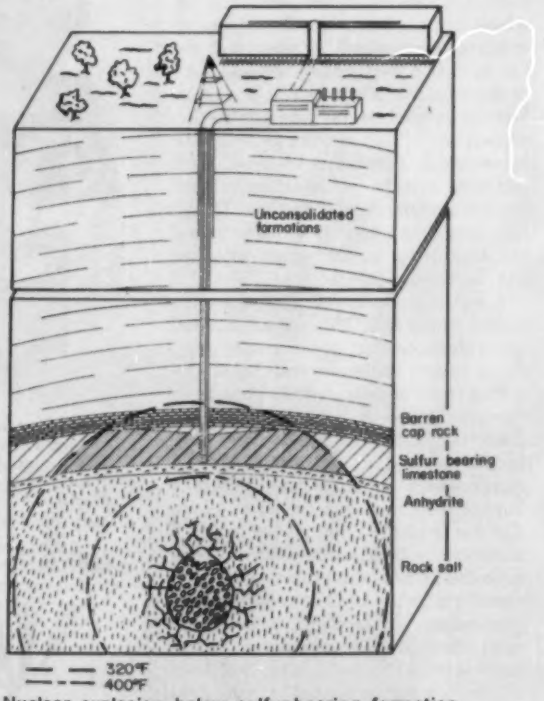


Nuclear explosion in the sulfur-bearing formation.



Nuclear explosion below sulfur-bearing formation.

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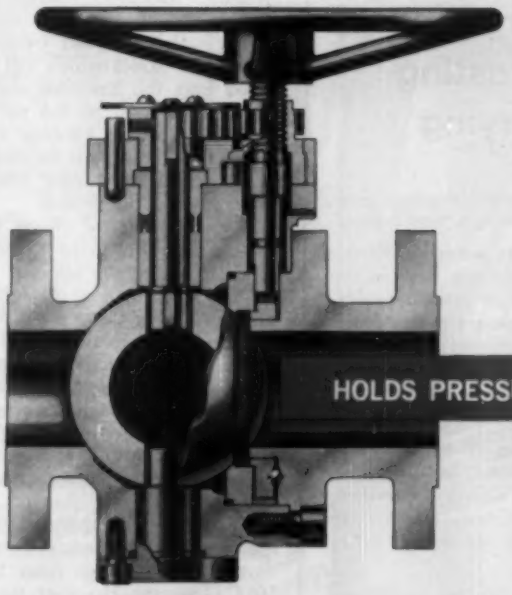
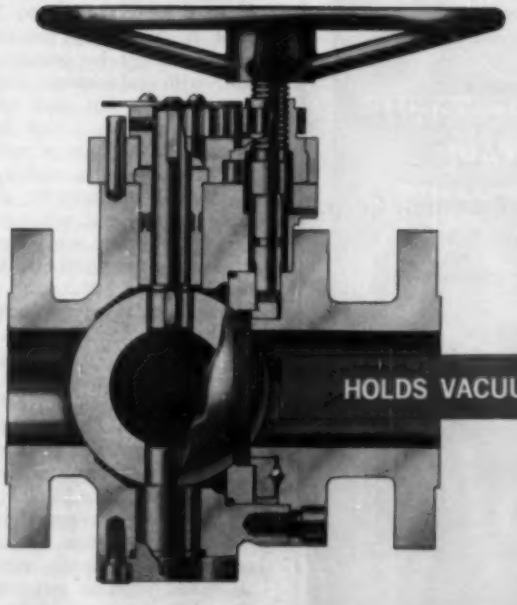


HOLDS PRESSURE



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●

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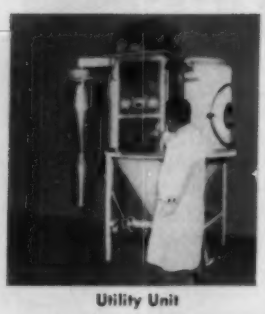

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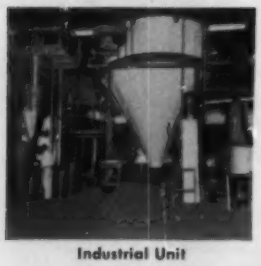

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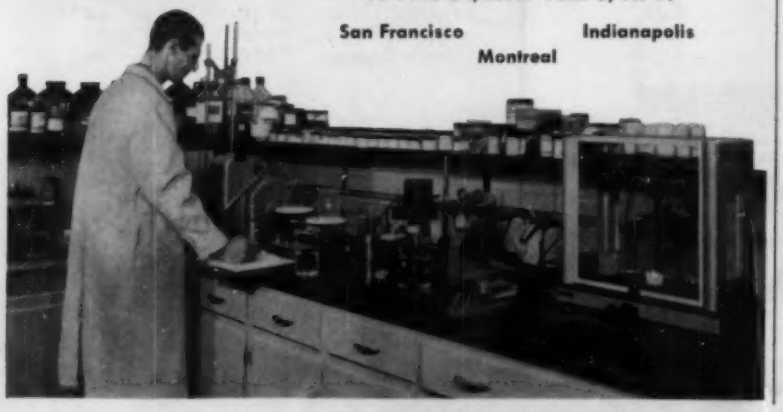

For more information, turn to Data Service card, circle No. 84

Sulfur

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given for the entire blast area to cool off. Such a cool-off period would also allow the radioactive material to decay.

Since limestone is associated with the sulfur in the cap rock of the salt dome, it is believed that the energy released to the limestone will likely produce large quantities of carbon dioxide gas which might serve as a heat transfer agent and/or a lifting medium. Ground water, flowing around and through the cap rock, might leach the fused calcium and magnesium oxides which will be produced from the limestone and which will contain most of the radioactive materials. Possible solution—insoluble glasses for holding this material might be produced by adding silica sand when placing the device.

If the detrimental effects of overheating the sulfur make it disadvantageous to locate the blast in the sulfur-bearing formation, it might be desirable to lower the point of the blast into the salt dome and melt the sulfur above by conduction (Figure 2). When the thickness of the sulfur-bearing formation is small, lowering of the blast point would appear highly desirable. This would also greatly reduce radioactive contamination of the sulfur.

Thermal conductivity of the more common formations encountered in the earth's surface range from 1 to 5 x 10^3 C.G.S. units. However, the thermal conductivity of rock salt varies from 8 to 15 x 10^3 C.G.S. units. The fact that it is dry would prevent great losses of energy by conversion into steam, with subsequent dissipation. It is estimated that each kiloton of energy released in a salt formation will raise 3,000 tons of salt up to 1,500°F, above the melting point. The thermal conductivity of sulfur-bearing calcite and anhydrite is in the range of most earth formations; this suggests the possibility that heat generated in the salt formation would be transferred to a wide area of the sulfur-bearing formation above the salt.

Since salt domes in the Gulf Coast area originate from a mother salt formation, it would be possible to consider deep-seated domes as a location for trapping heat for later use in producing sulfur. At 15,000 feet, it would be feasible to consider use of a 30 megaton explosion, since ground shock decreases rapidly with depth. This would yield an estimated 2,400 million kilowatt hours of energy.

Extraction of the sulfur

By setting off a device that would be contained within the salt of a dome, a desirable procedure might be to drill directional wells from the surface down through the sulfur-bearing cap rock into the heat pocket. By running various strings and selective perforations, it would be possible to pump water into the heat pocket. The steam thus generated would travel up into the sulfur-bearing formation, and the sulfur would then be lifted to the surface through a separate annulus.

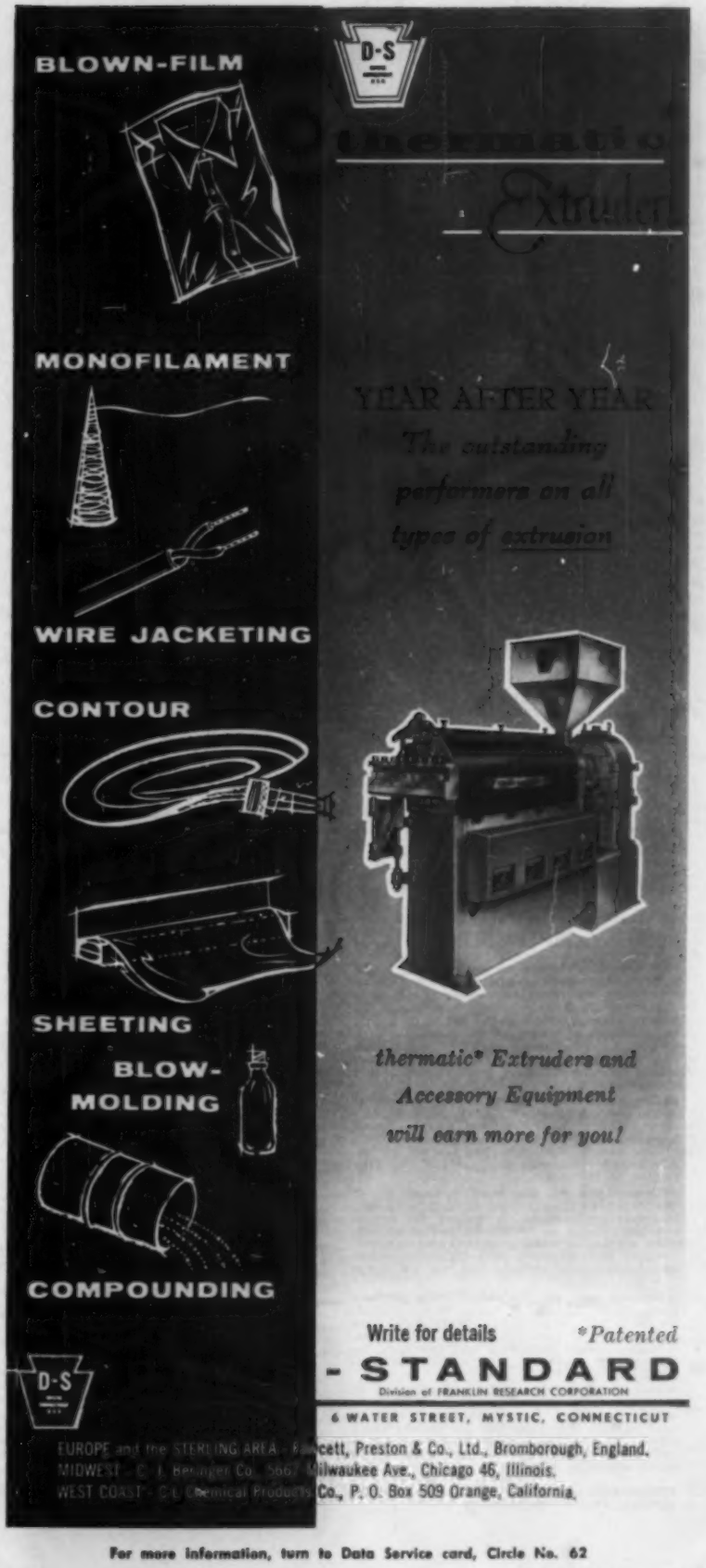
Another possibility is that, after setting off a nuclear explosion, the sulfur recovered from a well drilled into the center of the blast area and into the bottom of the cavity formed by the detonation could be used to heat water, which could then be pumped into outlying wells on the periphery of the site, forcing the liquid sulfur toward a center well, in a fashion similar to that used in oil field water flood projects. This procedure, in effect, would permit reuse of the heat generated by the detonation.

Economic feasibility

In using a nuclear device for mining sulfur, it is believed that the simplest of devices would be both sufficient and desirable. Efficiency in utilization of the energy generated would appear to be very high, since the heat generated would be imparted directly to the element to be heated, bypassing the various conversions and efficiency losses encountered in present-day power production techniques based on fossil fuels.

Preliminary cost calculations have been carried out based on a sulfur formation at a depth of 1,500 feet. The sulfur formation was considered to be 200 feet in thickness and to contain 35% sulfur by volume. The nuclear device was assumed to have been exploded in the sulfur formation.

It was calculated that, for a 10 kiloton device, temperatures above the melting point of sulfur will exist at a radial distance of about 120 feet from the explosion point. This temperature condition will be reached from 4 to 6 months after the explosion. At the end of this period, the amount of molten sulfur at a temperature of 320°F will be approximately 100,000 long tons. Based on recovery of 95% of this sulfur in 120 calendar days with a stream factor of 0.83, production would be approximately 40 long tons per hour. Preliminary analysis indicates that the cost of the sulfur produced would be between $6.00 and $8.00 per long ton.



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meeting preview

Tulsa—the technical program

Role of the chemical engineer in oil refining, petrochemicals will be main theme of A.I.Ch.E. September National Meeting.

THE OIL CAPITAL OF THE UNITED STATES, Tulsa, Oklahoma, will be host to the upcoming A.I.Ch.E. National Meeting, September 25-28.

In keeping with the surroundings, the technical program will lay heavy emphasis on the increasingly important role of the chemical engineer in oil refining and in petrochemicals.

Two complete sessions on *Advances in Refinery Technology* will present new data on such varied topics as residue processing, hydrogenation, low-temperature recovery units, molecular sieves, catalyst airlifts, control computers for fractionation units. Also directly in the petroleum field will be two sessions on *Multiphase Flow in the Production and Drilling of Oil Wells*, and two on *Natural Gas and Natural Gas Liquids*.

Safety first

Continuing A.I.Ch.E.'s long-standing campaign for free exchange of information on chemical plant operating safety, five whole sessions will be dedicated to *Safety in Air Separation and Ammonia Plants*. While a certain number of prepared presentations have been scheduled, most of the time at these discussions will be open for speakers from the floor. This September in Tulsa, in addition, the safety drive has been extended to include two additional sessions of the same nature on *Safety in Refinery and Natural Gasoline Plants*.

The symposium on *Petrochemicals* will include data on several new processes, as well as two or three papers dealing with market potentials and general trends in the area.

Design engineers will crowd the symposia on *Materials of Construction* and *Corrosion*, while those of a basic theoretical turn of mind will find solid fare in the two go-arounds on *Non-Newtonian Fluid Mechanics* and the two on *Statistics and Numerical Methods Applied to Engineering*. Also of theoretical as well as practical interest will be a technical session on *Chemical Reactions Induced or Modified by Radiation*.

Brave new world

Communications between man and machine, use of computers in equipment design and planning of plant operations—all this and more in the two symposia on *Computers as a Management Tool*—a must for executives in being and in training.

The program will be rounded out by two sessions on *Industrial and Engineering Applications of Foaming Techniques*, and one each on *Processing Agricultural Products, Conservation and Utilization of Water*, and *Piloting, or Why Buy the Restaurant When All You Need is a Meal*. Plus—three complete sessions of *Selected Papers*.

The complete program is given below. Details of planned extracurricular activities, plant tours, where to go and what to see in Tulsa will follow in *CEP's* August issue.

Three-Day Schedule of Technical Sessions

MONDAY, SEPTEMBER 26

9:00 A.M.-12:00 NOON

TECHNICAL SESSION NO. 1—ADVANCES IN REFINERY TECHNOLOGY—Part 1

Chairman: W. C. Offutt, Gulf Res. and Devel. Co-chairman: C. Berg, Union Oil of Calif.

Development of model II fluid coker, R. O. Wright, A. L. Saxton, & H. N. Weinberg, Esso Res. and Eng. An improved version of fluid coking for conversion of residual stocks into more valuable distillate products.

Recent advances in the technology of residue processing, H. Beuther, J. B. McKinley, & R. A. Flinn, Gulf Res. and Devel. Recent methods for processing residues to produce higher quality fuel oils. The nature of asphalts and techniques for treating and conversion of residues.

Hydrogenation by the H-oil Process, M. C. Chervenak, C. A. Johnson, & S. C. Schuman, Hydrocarbon Research. A system, for hydrogenating petroleum stocks, which gives efficient contact between reactants and catalyst, freedom from pressure drop difficulties, absolute temperature control, and low net catalyst consumption.

Operating data for low-temperature recovery units, D. D. Roselius & Roger Wylie, Humble Oil and Ref. Vapor-liquid equilibrium data for mixtures of light hydrocarbon compounds, nitrogen, carbon monoxide, and hydrogen, together with operating data for an ethylene-ethane splitter.

Molecular sieves in process separations, K. Kiyonaga & G. J. Griesmer, Linde. Ways in which molecular sieve adsorbants can be used in fixed bed cycles and the factors which affect the economies of bulk separation. A hydrocarbon separation process is presented as an example.

TECHNICAL SESSION NO 2—NON-NEWTONIAN FLUID MECHANICS—PART 1

Chairman: A. B. Metzner, Univ. of Del.

Velocity profiles in rectangular ducts, R. S. Schechter, Univ. of Texas. The velocity distribution for laminar flow of a power law fluid established and used to determine friction factor plots.

Laminar flow of non-Newtonian fluids through packed beds, N. Caniaris & H. Brenner, N. Y. Univ. Pressure drops due to flow of various suspensions through beds of spheres determined and correlated.

Flow of non-Newtonian fluids in a magnetic field, T. Sarpkaya, Univ. of Neb. The analytical solution to the equation of motion for steady flow between parallel planes for the Bingham plastic and the power law models.

Laminar, non-isothermal flow of non-Newtonian fluids, E. B. Christiansen & R. W. Hanks, Univ. of Utah. Numerical solutions to flow equations of fluids represented by a temperature dependent Ostwald-de Waele equation presented in graphical form.

TECHNICAL SESSION NO. 3—SAFETY IN AIR SEPARATION AND AMMONIA PLANTS—PART 1

Chairman: G. U. Weigers, American Cyanamid.

An open forum for the discussion of items pertinent to the safe operation of air separation and ammonia plants. A number of prepared presentations have been scheduled.

- **A. Report of the subcommittee for safety in air separation and ammonia plants.** Summary of survey of this industry's safety practices.
- **B. Air separation plant safety, Part 1.** Air intake, air compressors, silica gel adsorbers, expansion engines and turbines, reboilers and vaporizers.

TECHNICAL SESSION NO. 4—SELECTED PAPERS SESSION

Co-chairman: R. H. Perry, Univ. of Okla.
Co-chairman: J. E. Powers, Univ. of Okla.

Minimum reflux for multicomponent distillation systems, R. C. Erbar, California Research, & R. N. Maddox, Okla. State Univ. A rigorous method for calculating the minimum reflux for multicomponent systems.

Correlations for multicomponent distillation calculations, J. H. Erbar & R. N. Maddox, Okla. State Univ.

Thermal conductivities of porous rocks filled with stagnant fluid, D. Kunii & J. M. Smith, Northwestern Univ. Conductivities for four types of sandstone filled with various gases and liquids. Results correlated to predict heat transfer characteristics of porous sandstones.

Micromechanisms of oil displacement from porous media, C. C. Mattax, J. R. Kyte, C. D. Russell, Jersey Prod. Res. A visual flow model and results of tests.

Mechanism of oil recovery by surfactant displacement, P. J. Berkeley, Jr., B. P. Ewing, Jr., C. C. Mattax, & J. E. Shewmaker, Jersey Prod. Res. Surfactant solutions improve oil displacement from water-wet porous media.

TECHNICAL SESSION NO. 5—STATISTICS AND NUMERICAL METHODS APPLIED TO ENGINEERING—PART 1

Co-chairman: R. L. Heiny, Dow Chemical.
Co-chairman: D. J. Kaufman, Monsanto Chemical

A procedure for sequential experimentation, Edwin C. Harrington, Jr., Monsanto Chemical. Hypotheses are formulated, tested by experiment, and reformulated sequentially until the hypotheses satisfactorily predict the results.

Autocorrelation and optimum experimentation in chemical processes, J. Chanmugan, Princeton Univ. & G. M. Jenkins, Imperial College of Science and Technology, London, England. If the nature of a correlation is known, opti-

mum systematic design may be derived with increased efficiency by not randomizing.

Statistical program planning for process development, E. A. McCracken & Jesse M. Carr, Jr., Humble Oil and Ref. The use of highly fractionated factorials to screen a large number of variables saves time and aids in the interpretation of future data. An example of such sequential process development is presented.

Random number methods in process simulation, D. R. Petersen, Dow Chemical. Random numbers used to simulate, within a digital computer, natural variables commonly met in engineering problems.

Fitting yield and cost response surfaces to a fermentation product refining procedure, Elmer E. Lind, Jay Goldin, & John B. Hickman, American Cyanamid Yield and cost improvements in plant operation obtained by applying information for three controlled variables from data resulting from statistically designed laboratory experiments.

TECHNICAL SESSION NO. 6—PROCESSING AGRICULTURAL PRODUCTS

Chairman: Aaron Rose, Texas Engineering Experiment Station.

Chemical engineering and processing Southern agricultural commodities, J. J. Spadaro, N. B. Knoepfler, & E. L. Patton, U. S. Dept. of Agriculture. Chemical engineering research on oil-bearing materials, sugar cane and sweet potatoes at the Southern Regional Research Lab.

Process and product development in the grain processing industry, J. B. O'Hara, A. E. Staley Mfg. A description, with examples, of procedures used in process and product development.

New products from agriculture: processes, equipment and costs, K. M. Decossas, S. P. Koltun, E. F. Pollard, & E. L. Patton, U. S. Dept. of Agriculture. Agricultural utilization research offers industry numerous processes with equipment costs for producing new and improved products from cotton, oilseeds, citrus, pine gum, rice, and other farm commodities.

Relating the quality of solvent extracted soybean oil and residual oil content of meal, L. K. Arnold, R. B. R. Choudhury, & H. Y. Chang, Iowa State Univ. Flaked soybeans extracted in glass rate-extraction apparatus and in a continuous counter-current pilot plant.

Relationship between the weight and volume increases in steeping of cereal grains, L. T. Fan and D. S. Chung, Kansas State Univ. The volume gain by wheat kernels during steeping was practically equal to the weight gain divided by the fluid density.

2:00-5:00 P.M.

TECHNICAL SESSION NO. 7—ADVANCES IN REFINERY TECHNOLOGY—PART 2

Chairman: W. C. Offutt, Gulf Res. and Devel. Co-chairman: C. Berg, Union Oil of Calif.

The TCC Airlift, J. M. Bourquet, R. D. Drew, & S. Valentine, III, Socony Mobil Oil. Design of pneumatic catalyst lifts to give a favorable balance between capacity, efficiency, catalyst attrition, and costs.

Development of full-scale liquid thermal diffusion equipment, R. Grasselli, G. R. Brown, Standard Oil (Ohio), & C. E. Plymale, Owens-Illinois Glass. The development of equipment for liquid thermal diffusion separations traced from laboratory to pilot plant to full-scale unit. Flow patterns, heat transfer and separation efficiencies.

Reforming heavy catalytically cracked gasoline for high octane blend stock, R. F. Krest, H. W. Nagel, & H. E. Reif, Sun Oil. A route for producing a component for 105 R.O.N. premium motor fuel with high yield from catalytically cracked gasoline.

Application of controlling computers to fractionation units, A. A. Buster, Thompson-Ramo-Wooldridge. An overall closed loop system for fractionation. Some solutions for problems encountered.

The modern HF alkylation plant, E. R. Fenske, UOP. Design changes which have resulted in reduced capital investment, lower operating costs, and improvement in octane quality of product.

TECHNICAL SESSION NO. 8—NON-NEWTONIAN FLUID MECHANICS—PART 2

Chairman: A. B. Metzner, Univ. of Del.

Limiting pressure gradients in the flow of viscous fluids, W. E. Ball & R. E. Colwell, Monsanto Chemical. Temperature and velocity distributions calculated in the region where the magnitude of the shearing stress and pressure gradient which can be sustained by a viscous fluid may be limited.

A vorticity effect in anisotropic fluids, J. L. Eriksen, Johns Hopkins. Analyses indicate that the behavior of these fluids undergoes a qualitative change when a dimensionless measure of vorticity passes through a critical value.

Tulsa skyline across the Arkansas River from the giant Sunray refinery.

Non-Newtonian flow, R. S. Brodkey, Ohio State Univ. A universal velocity profile equation for turbulent flow obtained for the power-law approximation and compared with experimental data.

Turbulent velocity profiles—non-Newtonian fluids, A. B. Metzner & D. C. Bogue, Univ. of Del. Measured profiles for a variety of purely viscous fluids over a wide range of Reynolds numbers and flow behavior indexes.

TECHNICAL SESSION NO. 9—SAFETY IN AIR SEPARATION AND AMMONIA PLANTS—PART 2

Chairman: G. U. Weigers, American Cyanamid.

B. Air Separation plant safety. Part II. Oxygen handling, automatic safety equipment, turnaround schedules, inspections, maintenance, standards of cleanliness for oxygen equipment, materials of construction, use of combustible materials in oxygen plants, insulation.

TECHNICAL SESSION NO. 10—PILOTING, OR WHY BUY THE RESTAURANT WHEN ALL YOU NEED IS A MEAL

Co-chairman: D. O. Popovac, Continental Oil. Co-chairman: R. E. Weis, Phillips Petroleum.

Some principles of pilot plant operation, E. O. Saegebarth & H. M. Lavender, California Research. Examples used to show how pilot plant operations can be limited to the minimum necessary for confident process and plant design.

The pilot plant situation, J. P. Skelly, M. W. Kellogg. The practical need for complete or partial, pilot plants evaluated for several industries using specific references to pilot plant experiences.

Evaluation of calculations for bypassing pilot plants, D. H. White & R. A. Damon, Univ. of Ariz. Emphasis is placed upon similarity criteria and analog models in scale-up problems, unit operations equipment design, and certain aspects of momentum, energy and mass transport.

Considerations in non-integrated piloting, A. S. Brunjes, Lummus. Two small non-integrated pilot units and a bench scale unit used to derive sufficient information to design, construct and operate a phenol plant.

Scale-up of a novel mixer-settler extractor, R. B. Long, Esso Res. and Eng. Small scale mixer design studies led to the successful design of a commercial size mixer-settler extraction unit.

TECHNICAL SESSION NO. 11—STATISTICS AND NUMERICAL METHODS APPLIED TO ENGINEERING—PART 2

Co-chairman: R. L. Heinz, Dow Chemical. Co-chairman: D. J. Kaufman, Monsanto Chemical.

Reaction rate equations, J. W. Blakemore, Texas Instruments, & A. E. Hoerl, Du Pont. The erroneous effects of linearizing nonlinear rate equations and then fitting to the data. Hydrogenation of codimer used as an example.

Factorial quality control, C. C. Beazley, General Foods. A comprehensive breakdown of quality control data variation accomplished by rescheduled sampling and analytical testing.

An experiment to select optimum operating conditions on the basis of arbitrary preference ratings, A. M. Schneider, American Cyanamid, A. L. Stockett, Lehigh Univ. & G. Teplitsky, Lever Brothers. The object of the experiment was to scale up a gas scrubbing operation, with the response an odor acceptability which is not directly measurable.

The use of chi-square for preference testing in multi-dimensional problems, H. Smith, Jr. & P. N. Ries, Proctor and Gamble. Data obtained from a consumer preference test arranged in a four dimensional table and three factors studied for their effects upon the fourth.

On Kron's Animated Polyhedral models, J. L. Dolby, General Electric. A description of Kron's application of polyhedrons and multi-dimensional space filters to curve-fitting where more than one variable is involved.

TUESDAY, SEPTEMBER 27

9:00 A.M.-12:00 NOON

TECHNICAL SESSION NO. 12—PETROCHEMICALS

Chairman: H. L. Hays, Phillips Chemical.

Appraisal of potentials for petrochemical manufacture in the Southwest, J. M. Dale, Southwest Res. Inst. The Southwest as a source of raw materials, the trend in cost, petrochemical activity, and factors influencing future growth.

Sohio Acrylonitrile Process, F. Veatch, J. L. Callahan, J. D. Idol Jr., & R. C. Milberger, Standard Oil (Ohio). A review of the new process for direct conversion of propylene and ammonia with air to acrylonitrile.

Hydrocarbon oxidation with 95% oxygen, J. M. Robertson, Celanese Chemical. Reasons for use of 95% oxygen and certain important safety considerations.

continued on page 96

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Technical sessions

from page 95

Production of alpha-olefins. R. A. Frans, Monsanto Chemical. A paraffinic raffinate thermally cracked in the presence of steam to give a product from which alpha olefins were separated by distillation.

Recent developments in aromatic chemicals, R. Landau, Scientific Design.

TECHNICAL SESSION NO. 13—MULTIPHASE FLOW IN THE PRODUCTION AND DRILLING OF OIL WELLS—PART 1 (Co-sponsored by the Society of Petroleum Engineers).

Chairman: L. P. Whorton, Atlantic Refining.

The calculation of pressure gradients in high-rate flowing wells, P. B. Baxendall & R. Thomas, Compañía Shell de Venezuela. As a result of field experiments a correlation between energy loss factor and mass flow rate was established which is believed applicable to a wide range of conduit sizes and crude types.

Simultaneous flow of gas and liquid as encountered in oil wells, Shell Exploratie en Produktie Laboratorium. Four dimensionless groups found to be important in correlating pressure gradients. Results are in excellent agreement with field data.

Data on the simultaneous flow of oil and gas in wells and flowlines, F. Caponegro, Arabian American Oil. Results of more than 100 field tests.

Pressure drop for mist flow in a vertical tube, W. D. Leonard, Atomics International, A. O. Comer and J. H. Boggs, Okla. State Univ. Results of an experimental study and a correlation of pressure drop data.

The upward vertical flow of oil-water mixtures: The effect of oil viscosity, G. W. Govier, G. A. Sullivan, and R. K. Wood, Univ. of Alberta. Flow pattern, pressure drop and holdup data determined and correlated using 1, 20 and 150 centipoise oil.

TECHNICAL SESSION NO. 14—SAFETY IN AIR SEPARATION AND AMMONIA PLANTS —PART 3

Chairman: G. U. Weigers, American Cyanamid.

C. Ammonia plant safety, Part 1. Hydrogen source (special safety considerations), gas purification (other than nitrogen wash boxes), nitrogen wash boxes, compression.

TECHNICAL SESSION NO. 15—CONSERVATION AND UTILIZATION OF WATER

Chairman: Frank J. Lockhart, Univ. of Southern Calif.

TECHNICAL SESSION NO. 16—SAFETY IN REFINERY AND NATURAL GASOLINE PLANTS—PART 1

Chairman: J. N. Romine, Phillips Petroleum.

A group discussion with planned agenda. Each main topic will be introduced by an individual experienced in that field and will then be open for discussion from the floor. A free interchange of experiences and ideas by the audience will be encouraged.

Refinery explosions, M. V. Stuewe, Cities Service Oil.

Air compressors. P. F. Lindemann, Phillips Petroleum.

Furnace fires. E. J. Pratt, Humble Oil & Ref.

Engineering Safety into the plant, A. A. Sieg, Standard Oil (Indiana).

Risk analysis approach to safety, C. H. Austin, Standard Oil (Indiana).

Instrumentation for safety, J. F. Smith, Minneapolis Honeywell.

TECHNICAL SESSION NO. 17—SELECTED PAPERS SESSION

Co-chairman: R. H. Perry, Univ. of Okla.
Co-chairman: J. E. Powers, Univ. of Okla.

A kinetic model for vapors and liquids, R. J. Hengstebeck, Standard Oil (Indiana). A model for vapors and liquids. Based on this model, an equation of state developed for propane.

Phase correspondence and component distribution for complex systems, E. J. Hoffman, Univ. of Tulsa. Generalized expressions for K values and component distribution developed as functions of the boiling points of the components of a mixture.

A general correlation of vapor-liquid equilibria in hydrocarbon mixtures, K. C. Chao & J. D. Seader, Calif. Research. A modified principle of corresponding states supplemented by use of solubility parameters used for the correlation. Results of extensive tests of the correlation.

The correlation of binary and ternary liquid-liquid equilibria, T. C. Boberg, Jersey Prod. Res. R. R. White, Univ. of Mich. The

continued on page 98

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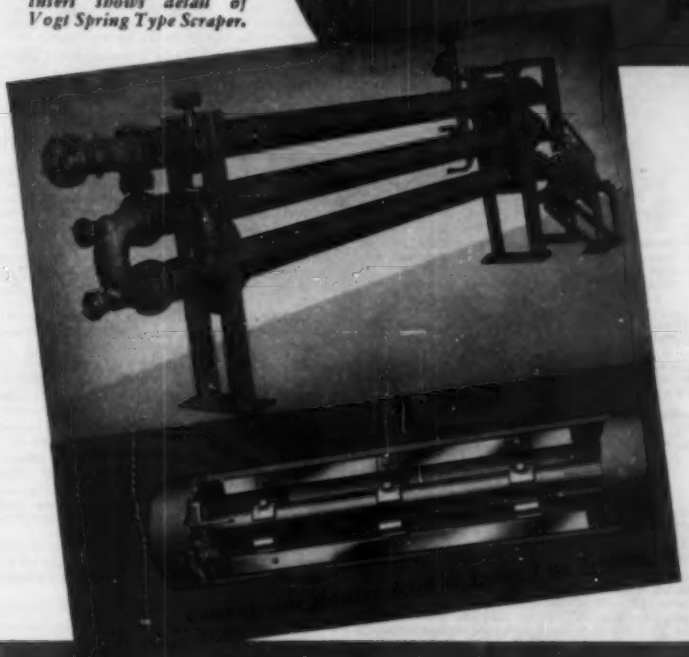

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- Paratone & Solids
- Phenolic Resins
- Polyester Liquid
- Pressed Distillate
- Reduced Petroleum
- Waxy Oil-Solvent Mix
- Soybean Oil
- Sperm Oil
- Sugar Syrup
- Sulfur-Oil Mix
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Technical sessions

from page 96

study of a varied range of systems indicates the feasibility of correlating liquid-liquid equilibria by digital computers using activity coefficients.

Vaporization equilibrium ratios for components above their critical temperature, D. S. Hoffman, R. E. Pelt, J. R. Welker, Univ. of Idaho, & J. H. Weber, Univ. of Neb. Values for the standard state fugacity of a hypothetical liquid above its critical temperature evaluated for methane, ethane, and propane.

1:30-5:00 P.M.

TECHNICAL SESSION NO. 18—MULTIPHASE FLOW IN THE PRODUCTION AND DRILLING OF OIL WELLS—PART 2 (Co-sponsored by the Society of Petroleum Engineers).

Chairman: L. P. Whorton, Atlantic Refining.

Multiphase flow of water, oil and natural gas through vertical flow strings, M. R. Tek, Univ. of Mich. A new correlation along with applications, working charts and example problems pertaining to the design of gas lifts.

Concurrent two phase vertical flow of air and Wilcox sand, J. E. Williams & R. L. Huntington, Univ. of Okla. Experimental pressure drop data show the effect of sand flowing rates as a function of air rate. Lift efficiencies range from 65% down to 1% and less.

Concurrent vertical flow of air and water, O. O. Carter, Phillips Petroleum, & R. L. Huntington, Univ. of Okla. A visual study in clear plastic tubing and correlations worked out for pressure drop and sweep and lift efficiencies. A motion picture shows flow patterns.

The reduction of pressure gradients in oil pipelines by addition of water: numerical analysis of stratified flow, M. E. Charles & P. J. Redberger, Research Council of Alberta. Velocity profiles, and oil and water flow rates evaluated for oil viscosities ranging from 20 to 1500 centipoise. Predictions compared with experimental results.

TECHNICAL SESSION NO. 19—SAFETY IN AIR SEPARATION AND AMMONIA PLANTS—PART 4

Chairman: G. U. Weigers, American Cyanamid.

C. **Ammonia plant safety, Part 2.** Synthesis, maintenance, storage and shipping ammonia, fire and emergency training for personnel.

TECHNICAL SESSION NO. 20—SELECTED PAPERS SESSION

Co-Chairman: R. H. Perry, Univ. of Okla.
Co-chairman: J. E. Powers, Univ. of Okla.

The effect of column length on separation in a batch thermogravitational thermal diffusion column, C. P. Crownover & J. E. Powers, Univ. of Okla. Effective lengths were varied from 14.5 to 72 inches in a column separating heptane-benzene solutions. Results substantiated theory.

Discrete film heat transfer in scraped heat exchange, O. K. Crosser, Univ. of Okla. An analysis of a heat transfer model predicts that for low conductivity materials, scraping efficiency and frequency are critically important.

Kinetics of reduction of ferrous oxide with hydrogen in a steady state fluidized bed, J. Feinman & T. D. Drexler, U. S. Steel. A correlation based on differential material balance and a controlling rate at oxide-metal interface predicts effects of independent variables upon kinetics of the system.

Mixing of solids, experiments with tumbling blenders, A. Kaufman, Merck, Sharp and Dohme Res. Lab. Experimental data obtained in a double cone blender and three twin shell blenders of different size. Preliminary conclusions drawn regarding the factors influencing mixer selection and scale-up.

Physical and operational features of a pulsed continuous countercurrent liquid-solids contactor, E. S. Grimmett & B. P. Brown, Phillips Petroleum. The effects of pulse frequency and amplitude in a two inch, five contact stage column. Ion exchange efficiencies determined for the copper-sodium (sulfate) and copper-hydrogen (nitrate) systems.

TECHNICAL SESSION NO. 21—SAFETY IN REFINERY AND NATURAL GASOLINE PLANTS, PART 2

Chairman: J. N. Romine, Phillips Petroleum.

Equipment inspection and intervals, A. L. McKillip, UOP.

Hidden and other hazards. Spontaneous ignition from iron sulfide, ventins and ventilation, static electricity, air in plant and pipe system. Any unusual experience which members of the audience would like to contribute.

WEDNESDAY, SEPTEMBER 28

9:00 A.M.—12:00 NOON

TECHNICAL SESSION NO. 22—CHEMICAL REACTIONS INDUCED OR MODIFIED BY RADIATION

Chairman: J. J. Martin, Univ. of Mich.

Sulfochlorination of cyclohexane induced by gamma radiation, J. C. Chu, S. Lawroski, ANL, & A. Schneider, Polytechnic Inst. of Brooklyn. Product was largely cyclohexane sulfonyl chloride. G values of the order of 10^3 to 10^4 obtained.

Hydrogen formation and scavenger action in the irradiation of hydrocarbons, alcohols and ketones, J. G. Burr, Atomics International. Radiolysis studies on benzene, biphenyl, benzophenone, and acetone dissolved in propanol, methanol, and cyclohexanone.

High temperature pile irradiation of the n-heptane-hydrogen system, G. H. Miley & J. J. Martin, Univ. of Mich. Radiation had an appreciable effect in the thermal cracking of n-heptane in the presence of hydrogen.

A one-megawatt organic chemonuclear reactor, L. E. Crean & L. S. Mims, Atomics International. Approximately 34 kilowatts of radiation power can be made available at a cost estimated to be less than that from an accelerator, cobalt-60 or cesium-137.

The utilization of fission fragment energy for the fixation of nitrogen, M. Steinberg, L. Green, & J. R. Powell, Brookhaven National Laboratory. Preliminary estimates indicate large reactors are required if process is to be competitive with existing commercial processes.

Fission fragment recoil effects on zirconium oxidation, W. C. Yee, E. E. Stansbury, G. H. Jenks, ORNL. Microscopic study of the surface films showed that recoil radiation had a definite effect on zirconium oxidation.

TECHNICAL SESSION NO. 23—INDUSTRIAL AND ENGINEERING APPLICATIONS OF FOAMING TECHNIQUES—PART I

Co-chairman: C. S. Grove, Jr., Syracuse Univ.
Co-chairman: R. L. Tuve, Naval Research Lab.

Novel uses for foam, C. S. Grove, Jr., E. J. Walker, A. R. Aldun, Onondaga Associates.

Temperature and viscosity effects of aqueous foams, Jablouski, et al, Naval Research Lab.

Thermal conductivity and insulating effects of aqueous foams, E. J. Walker, A. R. Aldun, K. E. Woodstock, Onondaga Associates.

Aqueous foams as fire extinguishing agents for liquid organic solvents, D. N. Meldrum & G. B. Geyer, National Foam System.

TECHNICAL SESSION NO. 24—SAFETY IN AIR SEPARATION AND AMMONIA PLANTS—PART 5

Chairman: G. U Weigers, American Cyanamid.

Informal discussion

TECHNICAL SESSION NO. 25—MATERIALS OF CONSTRUCTION

Co-chairman: W. A. Luce, Duriron.
Co-chairman: M. S. Worley, Black, Sivalls and Bryson.

Application of reinforced plastic pipe, W. Dana, Amercoat.

Behavior of noble metals (Ti, Zr, Cb) in Chemical Environment, F. Fink, Battelle.

Fluorocarbon polymers answer the challenge of corrosion, R. P. Bringer & C. C. Sovia, Minnesota Mining and Manufacturing.

Anodic protection against sulfuric acid corrosion, Locke, Hutchinson & Conger, Continental Oil.

TECHNICAL SESSION NO. 26—COMPUTERS AS A MANAGEMENT TOOL—PART 1

Chairman: R. Criner, W. R. Grace.

Co-chairman: P. Woodberry, W. R. Grace.

Computer design of catalytic reactors—viewpoint of the catalyst manufacturer, R. M. De Baum & S. P. Adler, American Cyanamid. Impact of computer methodology on the design of catalytic water gas shift converters.

Planning and scheduling of oil refinery operations, H. V. Fullerton, KCS Limited. Use of linear programming for seasonal planning of refinery operations and in the use of simulation for breaking seasonal plans into monthly operating schedules.

Cost determination by multiple correlation, K. H. Schaffir, Arthur Anderson & Co. Multiple correlation used to determine the true value of by-products used as a fuel in a power plant.

A management game for the petroleum industry, W. A. Viavant, Univ. of Okla., & M. Post, Texas Instrument Co. Use of general management games as a tool in teaching decision-making to executives; specifically, the construction of a mathematical model of an integrated petroleum economy.

TECHNICAL SESSION NO. 27—NATURAL GAS AND NATURAL GAS LIQUIDS—PART 1

Chairman: R. L. Huntington, Univ. of Okla.

Dynamic adsorption of isobutane and isopentane on silica gel, G. H. Dale, D. M. Haskell, H. E. Keeling, & L. A. Warzel, Phillips Petroleum. Studies using natural gas enriched with isobutane and isopentane. Results show effect of particle size, bed depth, gas velocity and concentration upon recovery.

Sweetening of liquid propane with molecular sieves, H. B. Rhodes, E. L. Clark, J. A. Lawrie, & R. A. Raidt, Linde. How these adsorbents are being applied commercially to remove the last traces of sulfur from liquid propane.

Recovery of helium by diffusion, K. B. McAfee, Bell Telephone Lab. How thin-walled capillary tubing may be used as a diffusion barrier to give essentially complete separation of helium from natural gas in one pass.

Carbon dioxide removal by hot potassium carbonate and amine scrubbing, H. S. Trail, Monsanto Chemical, J. C. Reynolds & R. E. Alexander, Girdler Const. Lessons learned from difficulties with earlier plants used to produce improved design.

2:00—5:00 P.M.

TECHNICAL SESSION NO. 28—INDUSTRIAL AND ENGINEERING APPLICATIONS OF FOAMING TECHNIQUES—PART 2

Co-chairman: C. A. Grove, Jr., Syracuse Univ.
Co-chairman: R. L. Tuve, Naval Research Lab.

Application of foaming agents to air drilling, A. S. Murray, Jersey Prod. Res.

The application of foaming agents to air and gas drilling, H. P. Downs, Technical Drilling Service.

Use of foams in oil well drilling and workover operations, J. L. Lummus, Pan American Petroleum.

TECHNICAL SESSION NO. 29—CORROSION

Co-chairman: W. A. Luce, Duriron
Co-chairman: M. S. Worley, Black, Sivalls and Bryson.

Designing to combat corrosion, R. C. Schueler, Phillips Petroleum.

Corrosion in the petroleum industry, W. Koger, Cities Service Oil.

Corrosion problems in petrochemical operations, G. Oladis, International Nickel.

Operating experiences in methanolamine acid gas removal systems, C. D. Polderman G. D. Hall, Union Carbide Chemicals.

TECHNICAL SESSION NO. 30—COMPUTERS AS A MANAGEMENT TOOL—PART 2

Chairman: R. Criner, W. R. Grace.

Co-chairman: P. Woodberry, W. R. Grace.

Language of the future, G. J. Haleh, Union Carbide. Present status of communications between man and machine reviewed and problems discussed.

Management's responsibilities in the use of computers, R. V. Lewis, W. R. Grace. Defining the practical limits of objectives and expectations in the successful installation and use of computers.

TECHNICAL SESSION NO. 31—NATURAL GAS AND NATURAL GAS LIQUIDS—PART 2

Chairman: R. L. Huntington, Univ. of Okla.

Natural gas pipeline operations under surge conditions, comparison of results of machine computations with field data, T. D. Taylor, N. E. Wood, & John E. Powers, Univ. of Okla. A mathematical model of a long pipeline formulated and several numerical solutions for machine computation developed.

A combination UOP Unifining-Platforming unit is on stream at the Ruhrchemie A. G. refinery in Oberhausen-Holten, Germany. Full range platformate from the 2000 BSD platforming unit is blended with light cracked gasoline from a catalytic cracking unit to produce a 94-95 octane number premium gasoline.

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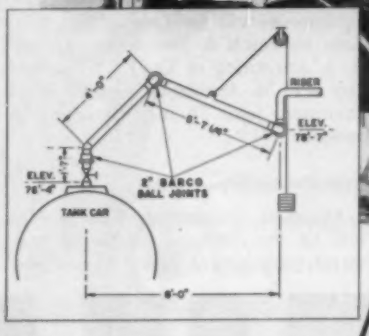

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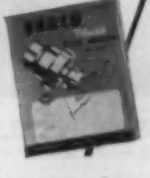

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meeting preview

Cracking the "operations barrier"

Keynote of coming Buffalo Heat Transfer Conference will be practical application. Equipment Exhibit will emphasize operating hardware.

PANEL DISCUSSIONS WILL hammer hard at the practical aspects of the gentle art of heat exchange, at the joint A.I.Ch.E.-ASME Heat Transfer Conference to be held this year at Buffalo, N. Y., Aug. 14-17.

Under the gavel of Don Kern, a Monday evening session will try to crack the "operations barrier" or, in other words, will try to analyze the oft-found resistance by operations groups to the incorporation of new methods and newtechniques into well-established plant practice. "A reversal of the usual sequence, starting with operations and proceeding back to research," believes Kern, "might supply new tools entailing less speculation at the design level and fewer operating problems after erection." Panelists will be: D. J. Bergman, UOP; C. H. Brooks, Sun Oil; C. H. Gilmour, Union Carbide Chemicals; A. C. Mueller, Du Pont. Comments from the floor will be welcomed.

Heat exchanger standardization

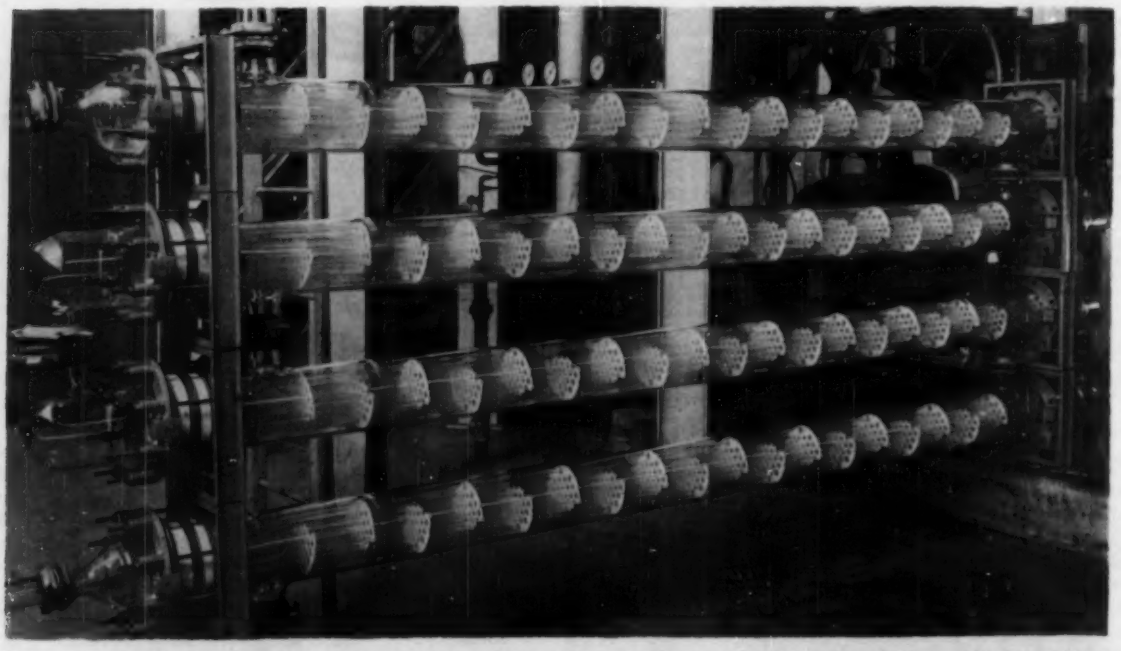
Heat exchange men cannot afford to miss the Tuesday evening panel on the standardization of heat exchanger design and fabrication. On hand will be representatives from both camps—manufacturers and users. Speaking for the makers will be Karl Gardner of Yuba Consolidated Industries, A. M. Mitchell of Struthers Wells, and Townsend Tinker of American Standard. On the other side of the fence—the people who use the equipment—will be Kalman Segel of Esso Research & Development, and R. J. Armstrong of Du Pont. Moderator is R. M. Armstrong, and the vice-chairman, John Thomas, Standard of Indiana.

Exhibit—Exhibit—Exhibit

Sideshow drawing card at Buffalo will be the extensive exhibit of heat transfer equipment, slated to run concurrently with the technical sessions and the panel discussions. Mounted by some of the most important manufacturers of heat transfer equipment, the booths will be manned by their crack engineering specialists, ready, able, and willing to help you with any conceivable sort of application problem. Here is your chance to inspect the actual hardware—your visit to Buffalo could well replace a dozen field trips to find out what you need to know about the latest designs, not only in heat exchangers, but in the most advanced combination reactor-processors, etc.

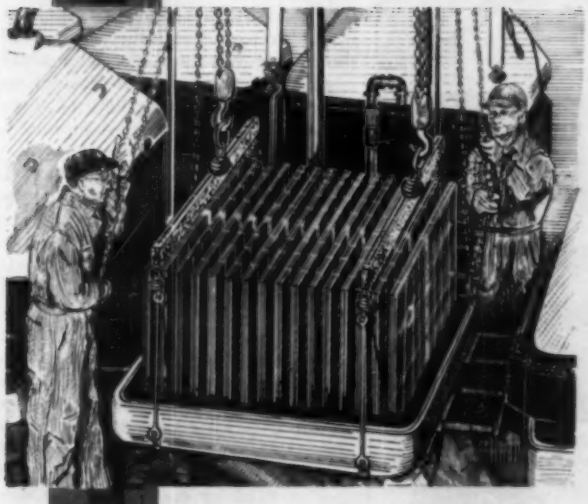
For the long-hairs

The differential equation boys will also find much to chew on at Buffalo. Several of the technical sessions will be devoted to the more basic approaches to heat exchange, equipment performance.



Glass, Teflon, and ceramic provide high corrosion resistance plus visibility in modular heat exchangers of Corning Glass.

GLC ANODES ARE CUSTOM MADE TO MEET VARYING ELECTROLYTIC CELL NEEDS



The custom made qualities of GLC Anodes give each cell operator performance characteristics best suited to his particular requirements.

These custom made qualities result from specialized anode production facilities, starting with the raw material mixing chambers and extending through extrusion, baking, graphitizing, oil impregnation and machining.

Equipment, designed exclusively for GLC, controls oil pickup to precise levels, and provides machining of superior accuracy. GLC Anodes are also distinguished for their uniformity of structure.

These factors combine to give GLC Anode customers improved cell operating economies that are a matter of record. May we review this record with you?

PRODUCTS ELECTRODE GLC DIVISION YOU CAN TRUST

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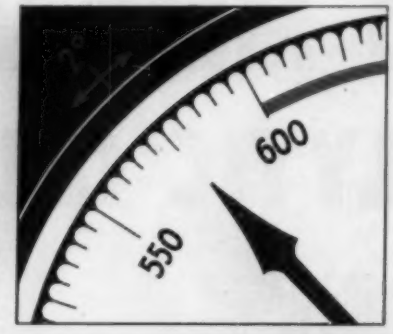
AROCLOR SYSTEMS DELIVER STEADY PROCESS HEAT TO 600°F and . . .

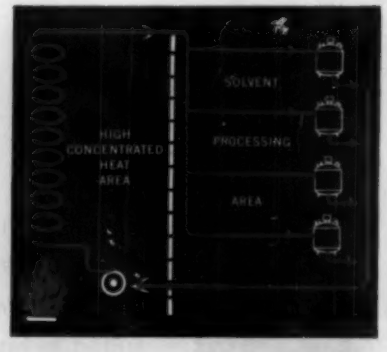
PINPOINT HEAT CONTROL . . .

to within 2° F. Indirect heating with Aroclor 1248 ends processing problems from local hot spots and overheating. Units range from small, portable electric types to large, gas- and oil-fired heaters generating up to 20,000,000 BTU's per hour. Typical uses: cooking of alkyd resins, dyestuff synthesis and other chemical reactions, deep-fat frying and other food processing, drying ovens and molding equipment.



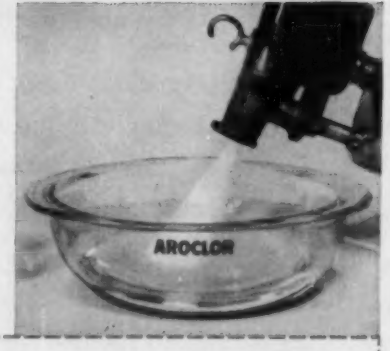
ECONOMY!

Unpressurized systems cost less to install and maintain than pressurized systems. Forced circulation of liquid Aroclor requires no condensers, vaporizers, traps, heavy-walled jackets or complex feed mechanisms. Compact design saves space. Heat from a single unit can be supplied for multiple uses at different temperatures. Total efficiency saves processing dollars.



FIRE SAFETY!

Even a blowtorch won't ignite fire-safe Aroclor 1248. A heating system designed with Aroclor 1248 eliminates the hazard of the vaporized, flammable fluid or danger of direct flame processing. Operating in a closed system vented to the atmosphere, these heating systems also eliminate the threat of "live" steam or chemical vapors escaping under pressure.



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industrial news

Chem engineer teachers attend cryogenics school

One day school held at Air Products plant covers chemical engineering theory, practice, in growing cryogenics field.

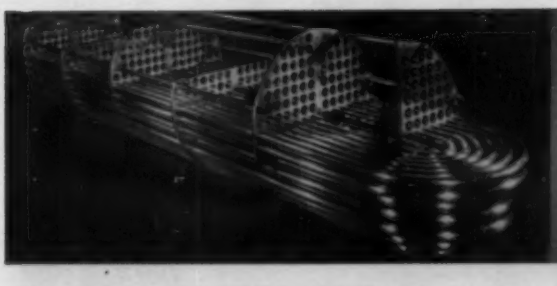
THIRTY-TWO CHEMICAL engineering teachers got a telescoped "education" in the cryogenics field when they recently attended a One-Day School for teachers. Conducted by Air Products at its Allentown, Pa., plant, and sponsored by the Education Projects Committee of A.I.Ch.E., purpose of the School was to sharpen chemical engineering theory and technology as applied to the growing field of cryogenics. The program was especially prepared to meet the modern day needs of the chemical engineering teacher by helping to bridge the gap between campus and industry.

Various phases of cryogenic engineering were presented by Air Products personnel in a series of technical sessions. Covered were: *Cycle Description and Heat Balance; Selection and Design of Heat Transfer Systems; Design of Distillation Systems; Refrigeration Cycles and Economics* (from a process designer's point of view, and from a machinery point of view). *An Introduction to the Field* and *A Look at the Future of Cryogenics* were beginning and ending features of the lectures.

Faculty members attending the School represented CCNY, Columbia, Cornell, Drexel Institute, Lehigh, Newark College of Engineering, Penn State, Brooklyn Polytech, Rutgers, Stevens Institute, Villanova, and the Universities of Delaware and Pennsylvania.

The A.I.Ch.E. Education Committee was represented by V. W. Uhl, Drexel Institute, who organized the project along with Air Products personnel. #

Production of pentaborane will begin at Callery's $38 million high energy fuel plant in Muskogee, Oklahoma, late this summer. The plant has been undergoing substantial modifications since the U.S. Air Force awarded the company a $9 million contract. The Muskogee plant is one of the military's principal sources for boron-based fuel in production quantities.



CONDENSER AND HEAT EXCHANGER CLINIC

Edited by David S. Hibbard, Metallurgical Engineer
The American Brass Company, Buffalo 5, New York

New tube mill equipment gives designer of heat-transfer units freer hand in meeting new trends

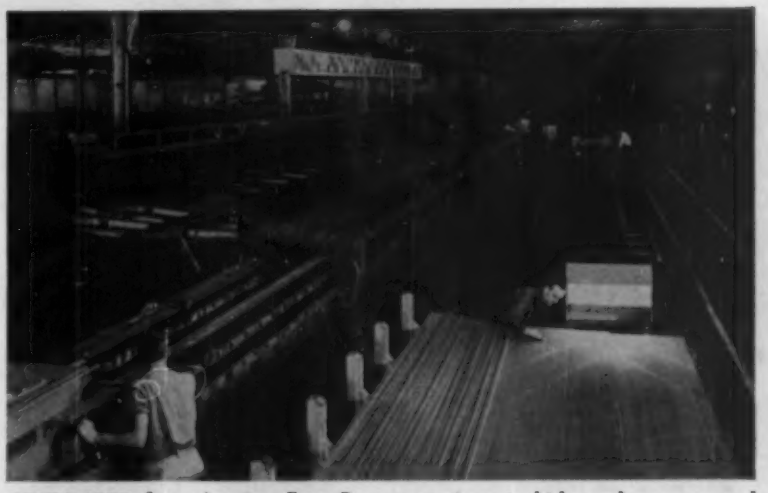
With the installation of new production and testing equipment, The American Brass Company now offers the most complete service available to users of condenser and heat exchanger tubes.

Long lengths. To gain advantages in construction, processing, or installation, designers can lengthen equipment considerably. Tubes can now be drawn up to 100 feet. Most of the longer tubes are required as U-bends, but in some instances may be shipped as straight lengths.

U-bends. Tubes from ⅜" O.D. to 1½" O.D. with wall thicknesses from .049" (18BWG) to .134" (10BWG) can be bent on a radius of from 1¼ times the tube O.D. to 30".

Dual Gage. Where high temperatures and pressures are involved, it may be desirable to thicken the tube wall in the area of short-radius bends on U-bend tubes. Walls are thickened one Stubs' Gage No. to compensate for thinning of metal in the bending.

Thickened Tube Ends. To compensate for thinning by rolling or by impingement corrosion caused by high velocities, tubes may be supplied with the wall thickened at one end one or more Stubs' Gage Nos. The extra thickness may be on the outside or inside of the tube as required.



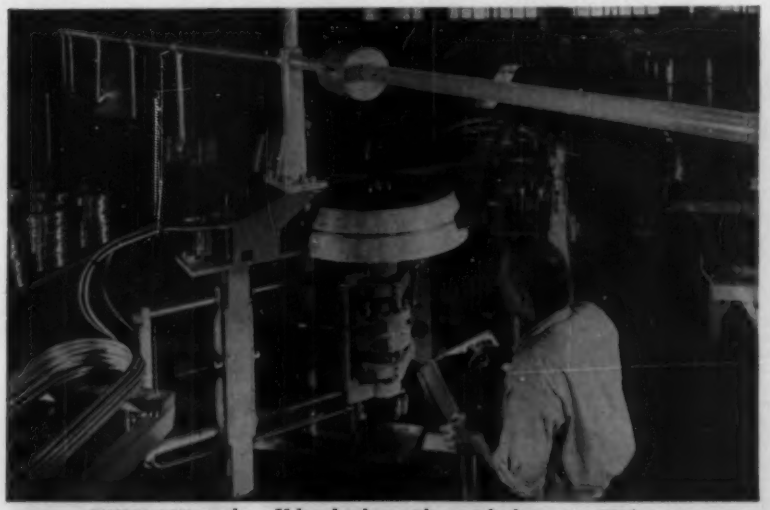
GENERAL VIEW of new American Brass Company equipment which can draw copper and copper alloy tubes in lengths up to 100 feet.

Relieving Stresses. All U-bend tubes, other than copper, are annealed at the bend area after bending, to eliminate the hazard of stress-corrosion cracking which might occur in service due to stresses that may exist as a result of the bending.

Testing. U-bends are tested hydrostatically at ASTM Specification pressures —or at ASME Code pressures up to 6000 psi on request, if the tube size will stand it. Electronic inspection with eddy-current equipment is available also, when required.

Shipping. U-bend tubes are shipped packed for ease in handling and storage.

Technical Assistance. For more detailed information on extra-long tubes, U-bend, Dual-gage, or Duplex tubes to meet special problems, address: The American Brass Company, Buffalo Division, Buffalo 5, New York. In Canada: Anaconda American Brass Limited, New Toronto, Ont.



BENDER CAN produce U-bend tubes with straight leg up to 50' long.

ANACONDA®

TUBES AND PLATES FOR CONDENSERS AND HEAT EXCHANGERS

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The American Brass Company

For more information, turn to Data Service card, Circle No. 44

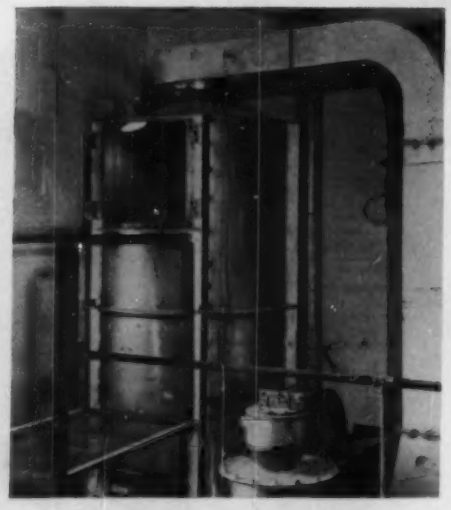
FACTS FIGURES AND IDEAS FROM BOWEN ENGINEERING, INC

Spray drying NEWS

VOLUME 2, NO. 4

RECOGNIZED LEADER IN SPRAY DRYING SINCE 1926

ONONDAGA ELECTRONICS DIVISION, SPEER CARBON CO. Cuts Processing Time 66% Produces a Better End Product



Spherical Free-Flowing Titanate Particles Produced By Bowen Semi-Works Ceramic Spray Dryer Shown, Result in Easier Pressing

Onondaga Electronics Division, Speer Carbon Co., of Syracuse, N. Y. one of the country's largest manufacturers of ceramic-based printed circuits, recently switched from the time-honored adobe process of drying barium titanates to the spray drying of titanate slurries with a Bowen Semi-Works Ceramic Spray Dryer. The result is what Onondaga Electronics Division management calls "the cheapest and very best way" to prepare barium titanates for pressing.

PROCESSING SIMPLIFIED—Prior to the installation of the Bowen unit, two men had to work for a total of three days to produce a batch quantity of a suitable body for pressing. The process used required the operations of mixing, oven-drying, grinding and then screening. Today, by use of the Bowen spray dryer, they can produce the same quantity within one day and obtain a vastly improved body that results in a more uniform pressing. The Bowen spray dryer produces a satisfactory range of particle size at a rate of from 50 to 100 lbs. per hour, depending on the concentration of the feed slurry.

DRYER QUICKLY AMORTIZED—Because this new process has eliminated several of the operations necessary in the old process and because it can produce a typical ball-mill batch in one-third of the time, the spray drying installation has paid for itself at a direct savings in about 15 months according to Onondaga Electronics estimates. (Actually, the Company estimates of amortization range from eight to 15 months depending on the amount of accessory equipment considered in the over-all cost analysis.)

The spray dryer is equipped with a special design of atomization which can handle very abrasive slurries with a minimum of wear. All parts of the equipment in contact with either the liquid feed slurry or the dry product are of stainless steel.

FREE-FLOWING PRODUCT—The most important advantage of the Bowen unit, however, is its ability to produce spherical particles. Acording to Mr. W. G. Fehrenbach, General Manager, even without the considerable savings in labor and operating cost, without which a greatly extended pay-out period would result, the Onondaga Electronics Division would still want to have the unit because of its ability to produce these spherical particles. "This achiveement," the General Manager says, "overshadows all other benefits," although he is quick to add that the other benefits are substantial. This spherical shape which is characteristic of spray drying, results in a more free-flowing product that fills automatic dies easily and readily and has a very low angle of repose. When compared to the jagged or irregular shapes of particles produced by any other process with relatively poor flow and pressing characteristics, it is easy to see why the Onondaga Electronics Division is enthusiastic about their Bowen spray dryer.

JAPAN'S FIRST CATALYST DRYER PLACED ONSTREAM BY BOWEN

Japan's first spray dryer for synthetic fluid catalysts and the largest spray dryer in operation in the Far East, has been placed onstream in Wakamatsu City for Shokubai Kasei Kogyo, K. K. (Catalysts and Chemicals Industries Company, Ltd.).

Bowen designed and engineered the unit for the subsidiary of Nihon Gasoline and Asahi Glass. It was erected under the supervision of Sumitomo Shoji Kaisha, Ltd., Tokyo, Bowen's Japanese representatives.

SPEAKING FOR BOWEN

DEXTER A. SMITH, *Bowen Vice President, discusses the ability of the spray drying process to frequently produce a superior end product.*

Q: How does a spray-dried product differ from a product dried by other methods?

A: Spray dried materials exhibit rather unique and distinctive characteristics which permit them to be readily distinguished, by visual examination and inspection, from the same materials dried by other methods. These particles are usually almost completely spherical and rather uniform in particle size. As a result of these two characteristics, material is usually very free-flowing, non-dusty, and has a very low angle of repose.

Q: How much control can a spray drying operation exercise over such variables as particle sizes, distribution etc.?

A: Control of spray drying process variables such as type and rate of atomization, drying temperatures, feed concentration, etc., permit rather precise control of the other dried product characteristics such as average particle size, particle size distribution, bulk density, and final moisture.

Q: What practical value does this have to the manufacturer considering spray drying?

A: The ability to determine product characteristics can mean two things:

1. *A superior end product for the producer to offer his customers and potential customers.*
2. *Sometimes the end product is so superior that markets are broadened or new markets are opened up. This is especially true where such factors as rate of solubility, rate of reaction, ratio of compaction in pressing, are of value in the final product use.*

The instances referred to on this page are only two of many applications in which the ability to control product characteristics within limits favors the spray drying operation over alternative processes.

Check items desired, clip and mail with your name, title and company address to Bowen Engineering, Inc., North Branch 13, N. J.

☐ Editorial Reprint OP

☐ Laboratory Spray Dryer Bulletin 31

Information on the feasibility of spray drying:

_____

_____

BOWEN ENGINEERING, INC.
North Branch 13, N. J.

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FOR MORE INFORMATION CIRCLE NUMBERS

SUBJECT GUIDE to advertised products and services

EQUIPMENT

Anodes, carbon (p. 101). Info from Great Lakes Carbon on facilities for custom production of anodes. **Circle 11.**

Can Coding Machine (p. 151). Technical details from J. M. Lehmann. **Circle 49.**

Castings, high-alloy (p. 113). Info from Duraloy on high-alloy castings for tubes and grids. **Circle 6.**

Compressors (p. 136-137). Cooper-Bessemer offers Bulletin on "Cooper-Bessemer Equipment for Chemical Plants." **Circle 32.**

Compressors, non-lubricated (p. 11). Reciprocating, centrifugal, rotary, ejector types. From ½ to 20,000 hp, pressures from one micron to 35,000 lb./sq. in. Data from Ingersoll-Rand. **Circle 78.**

Computer, analog, general purpose (p. 81). Info from Computer Systems on the DYSTAC, said to combine advantages of both analog and digital computers. **Circle 88.**

Computer, engineering design (p. 13). Application Report #10, and full technical details of the LGP-30 from Royal McBee. **Circle 90.**

Condenser, air-cooled (p. 160). Bulletin 129R from Niagara Blower gives details of the "Aero" vapor condenser. **Circle 52.**

continued on page 106

MATERIALS

Absorptives (p. 145). Diversey Corp., Div. of General Reduction, offers technical info, samples of Montmorillonite, used as carrier, extender, coating agent, etc. **Circle 126.**

Aerosols (p. 87-88). Production statistics for 1959 available from U. S. Industrial Chemicals. **Circle 119-1.**

Coatings, protective (p. 9). Bulletin 760 from U.S. Stoneware describes application of "Tygon" coatings to corrosion problems. **Circle 123.**

Diatomite (p. 115). Info from Johns-Manville on many grades of "Celite" diatomite. Consulting assistance with specific filtration or mineral filler problems. **Circle 27.**

Ethyl Acetate (p. 87-88). New Data Sheet from U. S. Industrial Chemicals gives specifications, properties, shipping info, uses of three grades of ethyl acetate. **Circle 119-5.**

Filter Materials (p. 138). Filter paper in complete range of sizes. Also filter cloth in many materials. Info from Filpaco Industries. **Circle 85-1.**

Gases, compressed p. 131). Catalog from The Matheson Co., Inc. gives full technical data and prices on 85 compressed gases. **Circle 100-1.**

Gases, compressed (p. 131). The Matheson Co., Inc. offers a Wall Chart: "Safe Handling of Compressed Gases." **Circle 100-3.**

Gases, process (p. 119). Info from Air Products on oxygen, nitrogen, argon, synthesis gas, ethylene, methane, HCl, CO, liquid hydrogen and liquid helium. **Circle 13.**

continued on page 106

SERVICES

Design and Construction, ethylene recovery plants (p. 109). Info from American Air Liquide on "pre-packaged" units. **Circle 75.**

Design and Construction, synthetic rubber plants (p. 139). Data from Lummus on design and construction of India's first synthetic rubber plant. **Circle 146.**

Fabrication, process equipment (p. IFC). Technical data from Wyatt Industries, Wyatt Metal & Boiler Div. **Circle 22.**

Heat Transfer Pilot Plant Facilities (p. 7). Complete pilot plant facilities available for determination of heat transfer coefficients on unknown materials. Info from Chicago Bridge & Iron. **Circle 8.**

Spray Drying Test Facilities (p. 92). Data from Nichols Engineering & Research on facilities for research, engineering, testing, custom drying at its Nerco-Niro Spray Dryer Div. **Circle 84.**

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CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 105*

Condensers, spiral (p. 27). Sizes from 15 to 1,600 sq. ft., pressures to 150 lb./sq. in. Info from American Heat Reclaiming. **Circle 110.**

Control, level, bin (p. 150). Detailed technical info from Bin-Dicator. **Circle 39.**

Control, liquid-level (p. 157). For all types of liquids. Horizontal, vertical, external mountings. Info from Jo-Bell Products on the "Level Master." **Circle 36.**

Control Systems, visual (p. 171). Booklet BE-20 from Graphic Systems. **Circle 60.**

Conveyors (p. 151). Data Book (88-page) from Continental Conveyor & Equipment. **Circle 34.**

Conveyors, belt (p. 111). Catalog Data from Stephens-Adamson Mfg. **Circle 20-2.**

Conveyor-Elevators (p. 111). Bulletin 349 from Stephens-Adamson Mfg. Gives details of "zipper" closed-belt conveyor-elevators. **Circle 20-1.**

Cooling Systems (p. 123). Info from Hudson Engineering on air, water, and combination systems. **Circle 137.**

Cylinder Valve Outlets (p. 131). Bulletin from The Matheson Co., Inc. **Circle 100-2.**

Deionizers (p. 148). From smallest laboratory to largest plant needs. Bulletins from Elgin Softener. **Circle 46.**

Dryers, double-shell (p. 141). Hardinge offers Bulletin AH-472 on double-shell, indirect-heat, gas-fired dryers. **Circle 114-2.**

Dryers, single-shell (p. 141). Bulletin AH-471 from Hardinge gives details of single-shell, direct gas fired rotary dryers. **Circle 114-1.**

Dryers, spray (p. 104). Technical info from Bowen Engineering. **Circle 148.**

Dryers, steam-tube (p. 141). Bulletin AH-473 from Hardinge. **Circle 114-3.**

Dryers, vertical, continuous (p. 144). Info from Wyssmont Co. on the "Turbo" dryer. Packaged units to 360 sq. ft. net. Field units to 18,000 sq. ft. net. **Circle 23.**

Eductors, water-jet, hopper-type (p. 31). Bulletin 2M from Schutte and Koerting gives sizes, capacities, ratios, water consumption, materials of construction. **Circle 56.**

Ejectors, jet-vacuum (p. 147). Bulletin from Jet-Vac. **Circle 82.**

Equipment, corrosion-resistant (p. 28-29). Data from Resistoflex on Fluoroflex (Teflon) chemical transfer hose, flexible joints, dip pipes, spargers, thermowells, condenser tube protectors, tower packing rings. Bulletin. **Circle 29.**

Extruders (p. 93). Details from Davis-Standard on "Thermatic" extruders and accessory equipment. **Circle 62.**

Fans, process (p. 14). Data from Garden City Fan & Blower on "Thermal-Aire" plug units. **Circle 93.**

Fans, rubber-coated (p. 96). Bulletin FD11 from Fly Ash Arrestor Corp. **Circle 130.**

Feeders (p. 5). Catalog 804 from B. F. Gump details the Draver feeder, available with automatic controls. **Circle 81.**

Filter Presses (p. 157). Complete Catalog from D. R. Sperry. **Circle 35.**

Fused Quartz Ware (p. 148). Complete Catalog from Thermal American Fused Quartz on "Vitreosil" industrial ware. **Circle 25.**

Gaskets, forged, seamless, ring (p. 171). Info from Southern California Oil Tool Co. **Circle 38.**

Generators, gas (p. 120). Packaged units for production of reducing, nitrogen, carbon dioxide, hydrogen, inert, and annealing atmospheres. Info from Gas Atmospheres, Inc. **Circle 149.**

Grinding Units (p. 141). Bulletin AH-448 from Hardinge describes dry and wet grinding units. **Circle 114-4.**

Heat Exchangers (p. 8). From non-ferrous to high-alloy steels, high pressure to vacuum, high to low temperature. Design and fabrication by Industrial Fabricating. **Circle 108.**

Heat Exchangers (p. 85). Info from Western Supply on importance of cost engineering in design and fabrication of heat exchangers. **Circle 2.**

Heat Exchangers, air-cooled (p. 10). From simple water coolers to the most complicated process coolers and condensers. Info from Smithco Engineering. **Circle 91.**

Heat Exchangers, air-cooled (p. 86). Catalog 557 from Young Radiator describes high-capacity, forced-draft, air-cooled exchangers featuring vertical air discharge. **Circle 61-2.**

Heat Exchangers, graphite (p. 14). Bulletin 156 from Heil Process Equipment gives data on shell and tube, immersion types. **Circle 43.**

Heat Exchangers, graphite-block (p. 30). Engineering Manual from Carbone Corp. gives details of the "Polybloc" exchanger. **Circle 74.**

Heat Exchangers, graphite, block-type (p. 152). Sixteen models, 4 to 500 sq. ft. Bulletin from Kearney Industries. **Circle 48.**

Heat Exchangers, low-pressure (p. 79). Bulletin 110 from Brown Fintube **Circle 109.**

Heat Exchangers, panel-coil (p. 23). Data Sheet 15-60 Series and Price Bulletin 259 from Dean Products. **Circle 26.**

Heat Exchangers, plate-type (p. 12). Designs to handle any pourable, homogeneous liquid. Technical info from Chester-Jensen. **Circle 103.**

Heat Exchangers, scraped-surface (p. 97). Technical info from Henry Vogt Machine Co. **Circle 41.**

Heat Exchangers, shell and tube (p. 86). New 4-pass design said to cut water usage by 75%. Catalog 1258A from Young Radiator. **Circle 61-1.**

Heat Exchangers, standardized (p. 33). Complete selection info in Bulletin B-20 from Struthers Wells. **Circle 40.**

Heat Exchangers, standardized (p. 130). Bulletin 158-HE from Doyle & Roth. **Circle 147.**

Heat Exchangers, standardized (p. 153). Bulletin 820 from Manning & Lewis. **Circle 50.**

Heat Exchanger Tubes (p. 103). Info from American Brass Co. describes new production and testing equipment available to users of condenser and heat exchanger tubes. **Circle 44.**

continued on page 108

MATERIALS *from page 105*

Heat Transfer Fluids (p. 98). Booklet on "UCON Heat Transfer Fluids" from Union Carbide Chemicals. **Circle 101-1.**

Heat Transfer Fluid (p. 102). Information Booklet from Monsanto Chemical on Aroclor 1248 heating systems. **Circle 76.**

Lubricants (p. 98). Booklet on "UCON Fluids and Lubricants" from Union Carbide Chemicals. **Circle 101-2.**

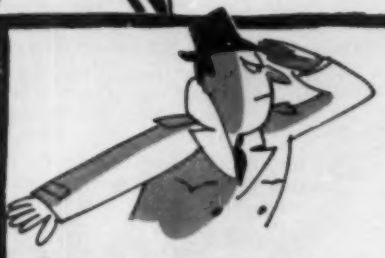
Metals, refractory (p. 116-117). Info from Fansteel Metallurgical on warehouse stocks of tantalum, tungsten, molybdenum, columbium, tantalum chemical processing equipment. **Circle 3.**

Methionine (p. 87-88). Info from U. S. Industrial Chemicals on dietary use. **Circle 119-2.**

Polyethylene, printing of (p. 87-88). Booklet from U. S. Industrial Chemicals gives methods of film treatment, printing techniques, inks, field test procedures. **Circle 119-3.**

Titanium (p. 87-88). Data from U. S. Industrial Chemicals on use of titanium in chemical process equipment. **Circle 119-4.**

HOW TO SLEUTH OUT THE TRUTH ABOUT EXPANSION JOINTS



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4 **Remember to look for accessories**

Full line of accessories — including covers and liners. Easy to pick proper combination of model, type and accessories for any pressure, temperature, erosive or corrosive condition.

5 **Pull an M.O. on the manufacturer's background**

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6 **Close the case — buzz Badger**

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CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 106*

Heat Transfer Systems (p. 125). Bulletin 597 from Parks-Cramer on high-temperature, low-pressure liquid-phase heat transfer systems. **Circle 42.**

Heaters (p. 146). Bulletin P-62 from Tranter Mfg. gives technical info on new "multi-zone" Platecoil, operating pressures to 250 lb./sq. in. **Circle 80.**

Heaters, process (p. 147). Bulletin 1300 from International Boiler Works describes the International-Lamont Aroclor Heater. **Circle 89.**

Icing Systems (p. 120). For effective cooling in chemical processing. Info from Flakice Corp. **Circle 58.**

Jet-Venturi Equipment (p. 124). Info from Croll-Reynolds on jet refrigeration, compressors, condensers, heaters, pumps, mixers, reactors, absorbers, fume scrubbers, special jet units. **Circle 31.**

Joints, ball flexible (p. 99). Catalog 215B from Barco Mfg. describes use of flexible ball joints for chemical loading arm service. **Circle 59.**

Joints, expansion (p. 107). Technical data from Badger Manufacturing. **Circle 33.**

Mixers (p. 36). New Handbook on Mulling from Simpson Mix-Muller Div., National Engineering. **Circle 12.**

Mixers (p. 159). For any type of chemical materials. Info from Rapids Machinery on the "Marion" mixer. **Circle 128.**

Mixers p. OBC). Mixing Equipment offers 4-page article on a heat-transfer correlation in a mixing vessel. **Circle 51.**

Mixer, portable (p. 89). Technical data from Gabb Special Products on the "Shear-Flow" portable mixer **Circle 4.**

Mixing & Grinding Equipment (p. 155). Complete info from Charles Ross & Son on kneaders, roller mills, mixers. **Circle 121.**

Nozzles, spray (p.24). Technical data from C. G. Sargent's Sons describes the SarJet, new design atomizing spray head. **Circle 55.**

Nozzles, spray (p. 144). In bronze, cast iron, stainless steel. Catalog from Spray Engineering. **Circle 84.**

Nozzles, spray (p. 160). Catalog 1 from Monarch Mfg. Works. **Circle 87.**

Processors, heat-exchange (p. 135). Technical data from Kontro on relative performance of horizontal and vertical wiped film processors. **Circle 124.**

Pulverizers (p. 158). Grind and classify in one operation in a single chamber. Bulletin 091 from Sturtevant Mill on the "Micronizer." **Circle 30.**

Pumps, centrifugal (p. 122). Technical data from Weinman Pump on centrifugals with capacities from 10 to 2,000 gal./min. **Circle 21.**

Pumps, controlled-volume (p. 26). Catalog 59 from Lapp Insulator gives technical data on the "Pulsafeeder," for flows to 15.7 gal./min., pressures to 7,000 lb./sq. in., manual or instrument controls. **Circle 5.**

Pumps, controlled-volume (p. IBC). For feeding of hazardous, corrosive, or toxic chemicals. Bulletin 1157-3 from Milton Roy. **Circle 115.**

Pump, process (p. 82). Can handle any pumpable corrosive fluid at temperatures from minus 350 to plus 1,000°F. Sizes from 1½ to 16 in. Bulletin 203-8 from Lawrence Pumps. **Circle 77.**

Pumps, turbine-type (p. 158). Bulletin 100 from Roy E. Roth gives mechanical details, performance curves on all sizes. **Circle 19.**

Pyrometer, surface (p. 155). Bulletin 4257 from Illinois Testing Laboratories describes the Alnor "Pyrocon." **Circle 7.**

Reactors, glassed-steel (p. 121). Bulletins from Pfaudler Permutit on full line of "Glasteel" reactors available for immediate delivery. **Circle 129.**

Recorder, "peak-picking" (p. 25). Catalog from Daystrom, Weston Instruments Div., on the Model 6707 Weston Peak Picking Recorder for gas chromatography. **Circle 125.**

Rectifiers, semiconductor (p. 153). Meaker Co., subsidiary of Sel-Rex, offers Guide to Industrial Rectifier Equipment. **Circle 54.**

Refrigeration Unit (p.145). Bulletin 9143-B from Ingersoll-Rand gives details of water-vapor refrigeration unit with steam-jet cooler. **Circle 79.**

Rotameters (p. 149). Bulletin 150 from Brooks Rotameter gives materials of construction, technical details. **Circle 14.**

Separation Equipment, liquids-solids (p. 133). Technical data from Bird Machine on oscillating-screen centrifuges, solid-bowl centrifugals, rotary-drum vacuum filters, pressure leaf filters, batch centrifuges, tilting-pan rotary vacuum filters. **Circle 45.**

Separators, entrainment (p. 4). Bulletin 21 from Otto H. York details applications of York "Demisters." **Circle 105.**

Separators, entrainment (p. 125). Bulletin ME-9 from Metal Textile discusses processing applications of "Metex" mist eliminators, knitted-wire entrainment separators. **Circle 17.**

Strainers, line (p. 146). For spray nozzle systems, related applications. Bulletin 94 from Spraying Systems. **Circle 92.**

Tanks, rubber-lined (p. 10). Complete info from Gates Rubber Co. **Circle 111.**

Tanks, stainless (p. 138). For storage and mixing, in all sizes. Data from Filpaco Industries. **Circle 85-2.**

Thermocouples (p. 32). Revised 40-page Catalog from West Instrument gives selection data, components, prices. **Circle 57.**

Thermocouple Wells, drilled (p. 154). Bulletin 2000 from Claud S. Gordon gives specs, sizes, ordering info on "Serv-Rite" drilled wells. **Circle 24.**

Transducer, electro-pneumatic (p. 150). With or without pneumatic valve positioner. Data from Fisher Governor on Type 543. **Circle 16.**

Tubing, heat-exchange, integral-fin (p. 19-22). Engineering data from Wolverine Tube on "Trufin" tubing, available in many types in copper, copper alloys, aluminum. **Circle 120.**

Tubing, Teflon (p. 149). Toughness and flexibility from minus 90 to plus 250°C. Info from L. Frank Markel & Sons. **Circle 37.**

Valves (p. 129). Wide choice of valve body and plug facing materials. Technical info from DeZurik. **Circle 15.**

Valves, ball-plug (p. 91). Catalog V-60 from Hydril gives full technical details. **Circle 122.**

Valves, corrosion-resistant (p. 38). In stainless, nickel, Monel, Hastelloy alloys, Ni-resist, aluminum, many other special alloys. Info from Wm. Powell. **Circle 10.**

Valve, flow-diverter (p. 156). Catalog from Systems Engineering & Manufacturing. **Circle 9.**

Valves, plug, jacketed, spring-loaded (p. 154). Bulletin J-57 from Hetherington & Berner. **Circle 47.**

Valve, safety-relief (p. 152). Pyrex and Teflon construction for seal against gases and liquids. Bulletin RV-1 from Chem Flow. **Circle 28.**

Vaporizers (p. 34). Bulletin ID-54-5 from Foster Wheeler gives complete details of high-temperature, low-pressure vaporizers. **Circle 102.**

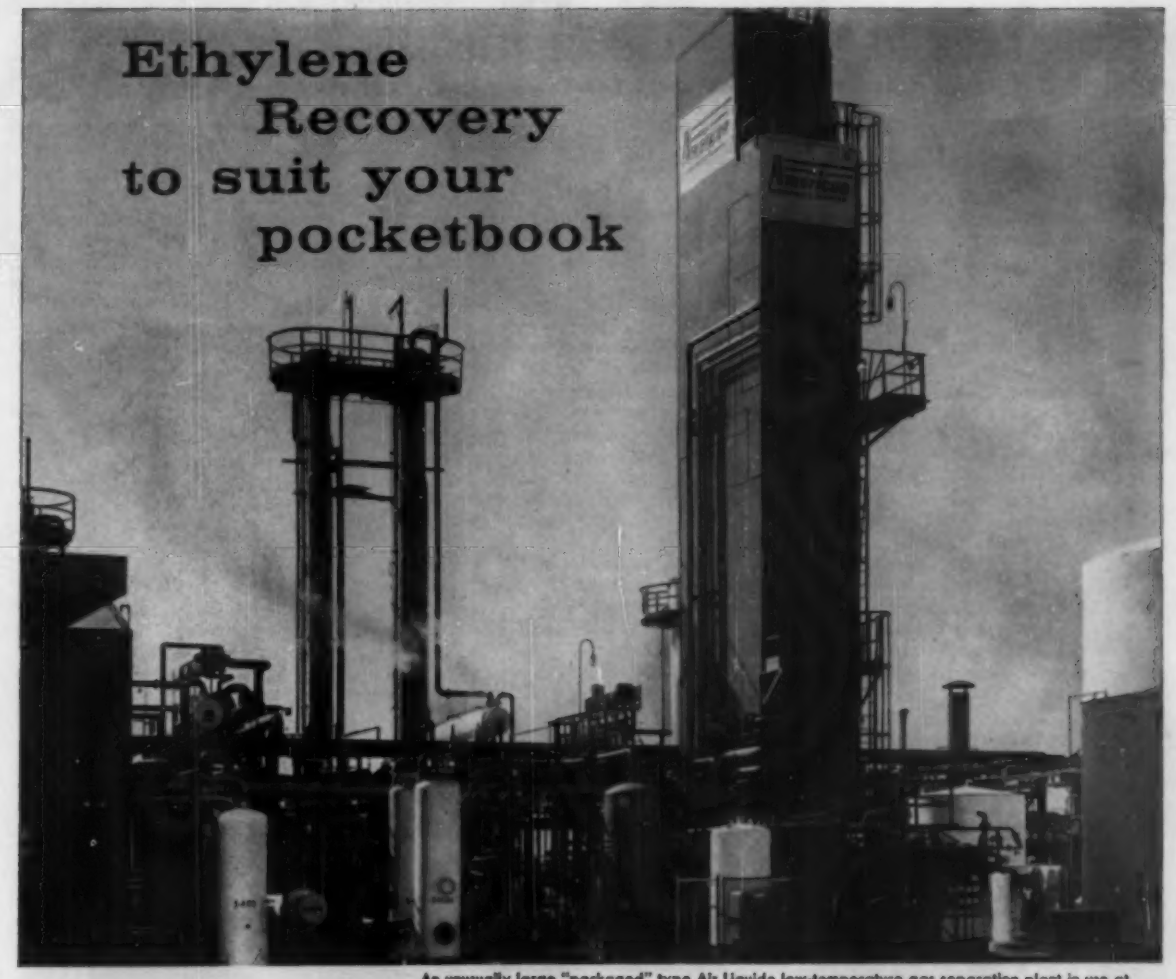
Viscometers (p. 132). Info from Brookfield Engineering Laboratories on applications of the "Viscometran" in process control. **Circle 1.**

Water Coils (p. 134). Bulletin R-50 from Aerofin Corp. gives full technical details of Type R removable-header water coils. **Circle 127.**

Weigher, continuous (p. 111). Bulletin 958 from Stephens-Adamson Mfg. **Circle 20-3.**

Wire Cloth (p. 83). For filtering, sizing, straining, testing. In all metals, all weaves. Bulletin FC from Newark Wire Cloth. **Circle 53.**

Ethylene Recovery to suit your pocketbook



An unusually large "packaged" type Air Liquide low-temperature gas separation plant in use at American Chemical Corporation's chlorinated-hydrocarbon manufacturing centre in California.

Lower capital outlay, elimination of over-production problems, and greater all-round design and operational flexibility. These are some of the positive advantages gained from the use of *low-temperature gas separation* in ethylene recovery.

Low-temperature separation permits the building of smaller units, which result in lower erection and operation costs. Air Liquide designs and builds these smaller units as "pre-packaged" assemblies, with capacities up to 100 tons or more per day.

During the past 30 years, Air Liquide has been recovering ethylene from effluent gases like coke-oven gas (containing 1.5 to 2%) and refinery off-gases (containing 5 to 15%) by the low-temperature process. And Air Liquide has built more ethylene recovery units and hydrocarbon separation plants than anyone in the world.

If you are thinking of ethylene recovery, check first with American Air Liquide.

Air Liquide has designed and built the following types of plants, now in use throughout the world:

• Air Separation — oxygen, nitrogen, etc. • Tonnage Oxygen and Nitrogen (Gas and Liquid) • Rare Gases Recovery • CO_2 Purification • Methane Purification • Natural Gas Liquefaction • Coke-Oven Gas Separation • Refinery Gas Separation • Hydrogen Liquefaction • Helium Recovery • Pure CO Production • Heavy Water for Atomic Reactors.

For complete information write or call

In Canada:
L'Air Liquide,
1210 Sherbrooke St. W.,
Montreal, Quebec.
Telephone Victor 2-5431

AMERICAN
AIR LIQUIDE
ENGINEERING & CONSTRUCTION DIVISION

Chrysler Building, 405 Lexington, Ave., New York 17, N.Y. Telephone: YUkon 6-6544

OLDEST IN EXPERIENCE NEWEST IN DESIGN

* **ALL AIR LIQUIDE LOW-TEMPERATURE PLANTS ARE DESIGNED AND BUILT IN NORTH AMERICA FROM AMERICAN MATERIALS, TO NORTH AMERICAN STANDARDS**

For more information, turn to Data Service card, circle No. 75

SUBJECT GUIDE to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT

301 Adsorption System, carbon. Catalog from Barnebey-Cheney outlines three basic units and operation of Resorb system.

302 Air Filter. Bulletin describing new cube air filter for low costs and easy installation from Union Carbide Dev. Co.

303 Compressor, centrifugal. Twelve-page Bulletin from Allis-Chalmers presents design features of multi-stage compressors.

304 Computer, analog. Information for new solid state computer CM-3 for process industries from Southwestern Industrial Electronics Co.

305 Computer, digital. Details from Packard Bell Computer Corp. describes PB250 general purpose computer.

306 Computer, gas flow. Data Sheet from Minneapolis-Honeywell gives applications of new analog computer for gas flow systems.

307 Computer Controller. Information for the Quarie computer controller from Fischer & Porter.

308 Conveying Systems, air. Question and answer Brochure from Flo-tronics Inc. discusses materials handling problem.

309 Detector, overheat. Brochure describes continuous resetting thermistor-type detector from Walter Kidde & Co.

310 Diaphragm Valves, graphite. Bulletin from Falls Industries contains details for new series of small diameter graphite valves.

311 Dissolvers. Information concerning a dissolver mounted on fixed tanks applicable to variety of mixing problems from Morehouse-Cowles, Inc.

312 Equipment, pilot plant. Specifications for line of reaction and distillation pilot plant packaged assemblies from Doyle & Roth Mfg. Co.

314 Filling Equipment. Eight-page Folder describes line of auger filling machines for powders, pastes, granules. Food Machinery & Chemical Corp.

315 Fittings, seamless welding. Bulletin from Midwest Piping Co. lists complete line of stock fittings.

316 Flow Tube. Descriptive literature for new "Lo-Loss" flow tube for accurate measurement of flow from Burgess-Manning Co.

317 Fluid Flow Rate Alarm. Bulletin from Brooks Rotameter Co. describes alarms for signalling or for simple control functions.

318 Fractionator Reflux Control. Instrumentation Data Sheet from Minneapolis-Honeywell describes method for controlling reflux ratio.

continued on page 112

MATERIALS

361 Aliphatic Chemicals. Twenty-page Booklet from Armour Industrial Chemical Co. describes production and uses of aliphatic chemicals.

362 Antioxidant. New 16-page Brochure from Eastman Kodak illustrates effectiveness of Tenamene-3 as an industrial antioxidant.

363 Beryllium. Brochures from Beryllium Corp. present properties and applications of the oxide and the metal.

364 Boron. A 24-page Booklet entitled "Borax and other Boron Compounds" from Stauffer Chemical Co. contains properties, reactions, uses of boron compounds.

365 Coatings Selector. Chart from Bee Chemical Co. contains list of surfaces with data on coating materials.

366 Cryogenic Gases. Wallet size and full-sheet size cards containing physical properties of cryogenic gases available from Air Products, Inc.

DEVELOPMENT OF THE MONTH

SAFETY CHART

(Circle 601 on Data Post Card)

A new 14" x 21" wall chart entitled "Using Compressed Gases," published by The Matheson Co., Inc., illustrates recommended procedures for the safe handling of compressed gases.

The chart, reported to be the first of its kind, shows the proper methods of receiving cylinders, storage, moving, handling empty cylinders, and using compressed gases.

To obtain a copy of this wall chart from The Matheson Co., Inc., Circle 601 on Data Post Card.

367 Diatomite. Bulletin discusses uses of diatomite in paper and pulp mills. From Dicalite Dep. of Great Lakes Carbon.

368 Fabrics, industrial. Information concerning industrial fabrics for fluid solid separation from American Machine and Metals.

369 Fluids and Lubricants, synthetic. Literature and samples of Ambiflo lubricants and fluids available from Dow Chemical Co.

continued on page 112

SERVICES

389 Air Pollution Control. A Booket from John Wood Co. discusses a planned approach to air pollution control.

390 Alloy Casting Publications. Booklet from Alloy Casting Institute lists technical reprints available.

391 Corrosion Guide. Booklet containing corrosion tables for metals, plastics, synthetic rubber used in valves from Hydromatics, Inc.

392 Dyeing of Synthetic Fibers. An 86-page Brochure from General Aniline & Film Corp. contains information on most important man-made textile fibers.

393 Heat Transfer. Article concerning radiant and convection heat transfer calculations from Carborundum Co.

394 Maintenance Cleaning. Booklet from Oakite Products, Inc. discusses the cleaning problem in the chemical industry.

395 Metal Chart. Table of properties for tungsten, tantalum, molybdenum, columbium and temperature conversion chart from Fansteel Metallurgical Corp.

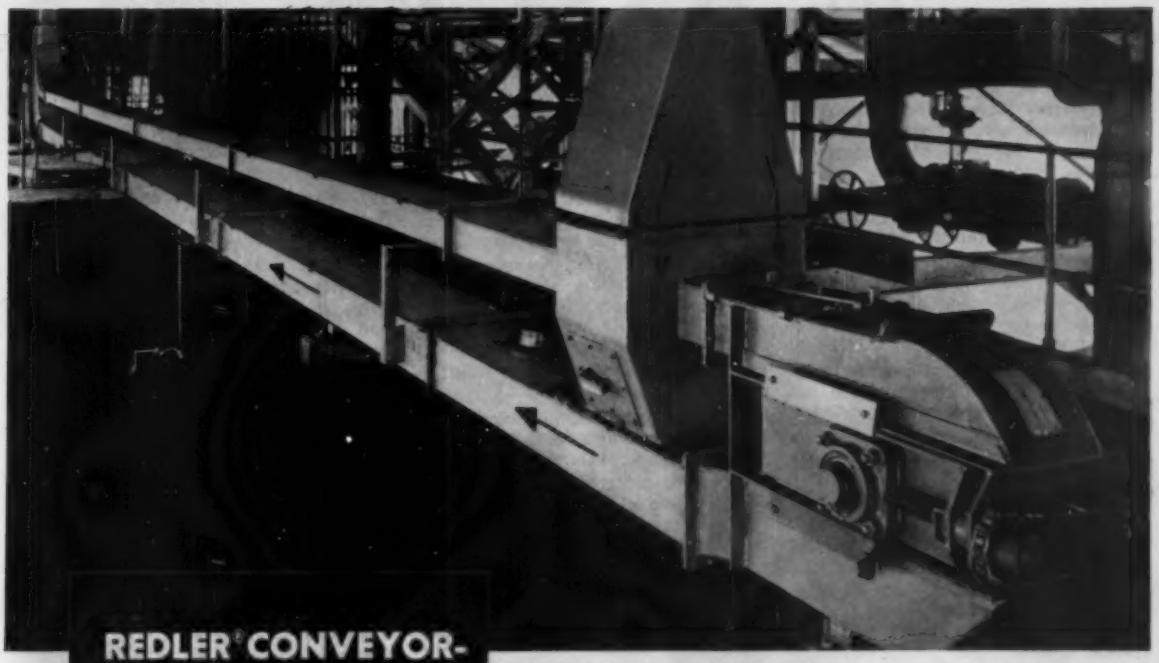
396 Periodic Chart. A periodic chart modified for nuclear design personnel is available from Westinghouse. A $1 handling charge will be billed directly. Do **NOT** send money to CEP.

397 Polymer Reprints. Two Technical Reprints on anionic polymerization of styrene and elasticity of polymer networks are available from the Mellon Institute.

398 Selection Chart, filler alloys. New welding aid for quickly specifying filler alloys for wrought alloy metal combinations available from Alcoa.

399 Solvents Transmittance. New 14" X 17" wall chart from Matheson Coleman & Bell shows U.V. and I.R. transmittance data.

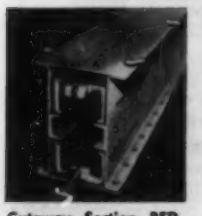
STEPHENS-ADAMSON



REDLER CONVEYOR-ELEVATORS SPEED EFFICIENCY, LOWER BULK CHEMICAL HANDLING COST

S-A REDLER Conveyor-Elevators have been in successful operation for over 25 years, with well over 20,000 units now handling a wide range of pulverized, granular, small lump and flaked materials, in plants throughout the world. The REDLER Conveyor-Elevator moves material by an EN MASSE action horizontally, vertically, on inclines, or around bend corners. All movement is continuous and takes place within totally enclosed, dust-tight, compact casings, permitting large tonnages to be handled in small space. The conveying element is a series of U-type skeleton flights which move readily around sprockets and bend corners with relatively low power required at the drive. Skeleton flights may easily be unhooked and replaced without tools. Handles up to hundreds of tons per hour and provides maximum versatility to handle hundreds of bulk chemical materials.

S-A ENGINEERED PRODUCTS FOR CHEMICAL HANDLING SYSTEMS



Cutaway Section REDLER Conveyor-Elevator shows skeleton flights loaded and unloaded.

"ZIPPER" CLOSED-BELT CONVEYOR-ELEVATOR—BULLETIN 349

BELT CONVEYORS—REQUEST CATALOG DATA

CONTINUOUS WEIGHER—BULLETIN 958

WRITE FOR BULLETIN 358

S-A
ENGINEERED BULK HANDLING SYSTEMS
SPEEDWALK PASSENGER CONVEYORS
SPHERCO BEARINGS & ROD ENDS

ENGINEERING DIVISION

STEPHENS-ADAMSON MFG. CO.

GENERAL OFFICE & MAIN PLANT, 57 RIDGEWAY AVENUE, AURORA, ILLINOIS

PLANTS LOCATED IN: LOS ANGELES, CALIFORNIA • CLARKSDALE, MISSISSIPPI
BELLEVILLE, ONTARIO

For more information, turn to Data Service card, circle No. 20

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 110*

319 Gyratory Screen. Bulletin from Allis-Chalmers presents operating advantages of stainless steel gyratory screen.

320 Heat Exchangers. Information for low cost, double pipe heat exchanger with improved assembly and maintenance features from Brown Fintube Co.

321 Heat Exchanger, graphite. Details for new heat exchanger units with recirculating pump from Heil Process Equip. Corp.

322 Heater, drum. Literature describing new model drum heater operated by pulleys and counter weights from Glas-Col Apparatus Co.

323 Heaters, unit and blast. Four-section Catalog from D. J. Murray Mfg. Co. describes cast iron heat units.

324 Impact Mill, centrifugal. Information from Entoleter describes mills for particle size reduction.

325 Industrial trucks, cost study. Four Booklets (62 pages) tells how to calculate and compare costs of industrial trucks. Details from Electric Storage Battery Co.

326 Instruments, laboratory. A 54-page Catalog describes complete line of industrial instruments from E. H. Sargent & Co.

327 Knife Cutters, rotary. Bulletin from Young Machinery Co. describes complete line of cutting equipment.

328 Linings and Coatings. Bulletin G-57 from Electrochemical Eng. & Mfg. describes acid and alkali-proof linings for industrial equipment.

329 Liquid Level Gages and Valves. New 8-page Catalog covers complete line of Jerguson liquid level gages and and valves.

330 Mills, attrition. Fifteen-page Bulletin contains complete line of attrition mills available from Young Machinery Co.

331 Mixer, shear-flow. New Brochure covering complete line of industrial mixers from Gabb Special Products, Inc.

332 Oven, infrared. Catalog containing facts and figures for electric infrared heating from Radcor, Inc.

333 Packings. Four Manuals containing information on molded packings available from Greene, Tweed & Co.

334 Pipe, data chart. New Chart from Peter A. Frasse & Co. covers dimensions and weights of steel pipe and gives capacities of tanks.

335 Pipe, Fittings, and Valves. Properties, chemical resistance, dimensions for rigid, unplasticized PVC equipment available from Luzerne Rubber Co.

336 Pipe & Fittings, graphite. Bulletin from Falls Industries describes both woven glass fabric armored and non-armored pipe and fittings.

337 Process Control. New 12-page Booklet outlines industrial process control systems offered by Daystrom, Inc.

338 Pulverizer, turbo. Literature covering turbo pulverizers and mills from Pallman Pulverizers Co.

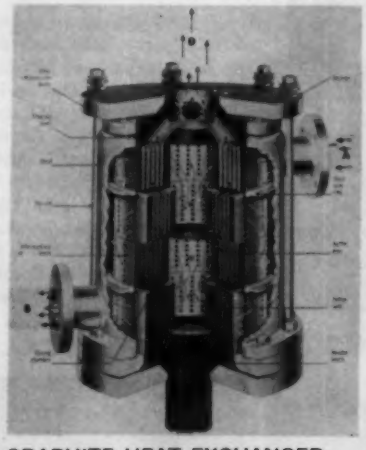
339 Pumps. New 32-page Catalog describes rotary positive air pressure and vacuum pumps, gas boosters from Leiman Bros.

340 Pumps, rotary. Engineering Selection Manual presents technical data for rotary pumps from Deming Co.

341 Pumps, rotary. Folder describes complete line of general purpose, heavy duty and special pumps from Viking Pump Co.

continued on page 114

DEVELOPMENT OF THE MONTH



GRAPHITE HEAT EXCHANGER

(Circle 602 on Data Post Card)

An impervious graphite heat exchanger offering complete resistance to almost all acids, alkalies, and solvents is available from the Carbone Corp.

The "Polybloc" exchanger shown above takes a corrosive liquid in at inlet C and passes this stream axially through short passages and mixing chambers in the graphite block. This arrangement is said to provide extreme turbulence, high heat transfer, and reduced scaling. The liquid exits at D.

The noncorrosive fluid enters at A and passes radially through the block to the center and back to the shell several times prior to exiting at B.

For more complete design and corrosion data from Carbone Corp., Circle 602 on Data Post Card.

MATERIALS *from page 110*

370 Gases, high purity. Sixteen-page Booklet from Linde Co. presents properties of gases, isotopic data for rare gases, physical data tables.

371 Graphite. Brochure describing industrial applications and characteristics of graphite from Great Lakes Carbon Corp.

372 Hexahydrophthalic Anhydride. A 17-page Booklet describes properties and uses of organic anhydride from Allied Chemical.

373 Hydrogen Peroxide. Five Booklets from Solvay Div. of Allied Chemical contain bibliographies on hydrogen peroxide.

374 Insulation. Details for new, high temperature Kaylo-Klad pipe insulation from Owens-Corning Fiberglas Corp.

375 Insulation. New Booklet contain-ASTM and government specifications and section on how to calculate economic thicknesses from National Insulation Mfg. Assoc.

376 Laminating Guide. A 24-page Daponite Laminating Guide available from Food Machinery and Chemical Corp.

377 Molybdenum Metal. A 110-page Book from Climax Molybdenum Co. contains enginering data for molybdenum metal.

378 Organics. Fifteen-page Brochure lists typical analyses of cresols, xylenol, cresylic acid available from Productol Co.

379 Organic Chemicals. New 21-page Brochure from Eastman Kodak lists properties and preparation procedures for derivatives of tetramethyl-1, 3-cyclobutanedione.

380 Packing, polyethylene. Packed tower data using unique packing available from Harshaw Chemical Co.

381 Pimelic Acid. Technical information from American Cyanamid describes pimelic acid used in making new polyester and polyamide resins and fibers.

382 Polyester Resins, corrosion tests. A copy of a corrosion test for polyester resins is available from Atlas Powder Co.

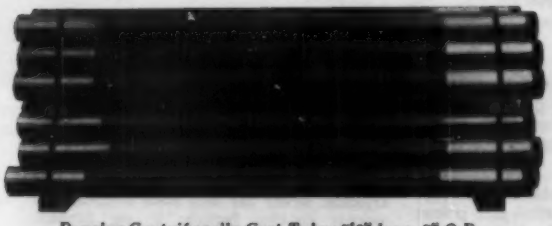
383 Polyvinyl dichloride. Bulletin from B. F. Goodrich Chemical Co. describes new hi-temp Geon.

384 Polyvinylpyrrolidone. New 22-page PVP Formulary issued by Antara Chemicals is guide to new products.

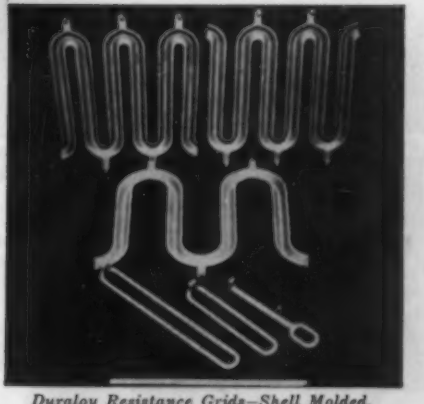
385 Sodium Aluminate. Brochure outlines industrial uses, physical and chemical properties of sodium aluminate from Nalco Chemical Co.

continued on page 114

Duraloy Tubes and Grids *to Meet Exacting* ELECTRIC EF FURNACE CO. GAS • OIL • ELECTRIC *Specifications*



Duraloy Centrifugally Cast Tubes 7'9" long, 7" O.D., ⅜" wall. 25 Cr 10 Ni; some of HOM alloy.



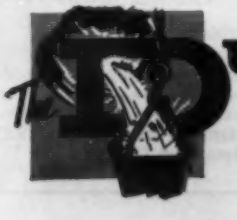
Duraloy Resistance Grids—Shell Molded. 18 Cr 38 Ni; some of special HOM alloy.

Heat treating furnaces need high alloy castings... radiant heat tubes for gas or oil fired... resistance grids for electrical... and castings for handling material through the furnace. *And the castings must be fail-proof!*

One reason—indeed the major reason—why The Electric Furnace Company, Salem, Ohio, has leaned so heavily on Duraloy for its castings is that over the years Duraloy Castings have established a fine record for durability and uniformity. And with the recent development of Duraloy HOM, the furnace company can work towards higher temperature operations. HOM can be used quite broadly at temperatures up to 2200°F and in a limited way to 2300°F. It can be cast statically, centrifugally and shell molded.

When such an authority on heat treating furnaces as Electric Furnace so consistently selects Duraloy castings for these furnaces on which it has built an enviable reputation... that preference suggests quite strongly that Duraloy castings are consistently sound and skillfully alloyed to meet exacting high temperature applications. This same skill offers comparable values to all who require high alloy castings.

Annealing furnace designed and constructed by The Electric Furnace Company used for cycle annealing of enameling iron strip and bright annealing of cold rolled strip. Three methods of heating: direct fuel fire; fuel fired radiant heat; and electric resistance used in the various zones.



DURALOY *Company*

OFFICE AND PLANT: Scottdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.

CHICAGO OFFICE: 332 South Michigan Avenue

DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

For more information, turn to Data Service card, circle No. 6

CEP'S DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD

EQUIPMENT *from page 112*

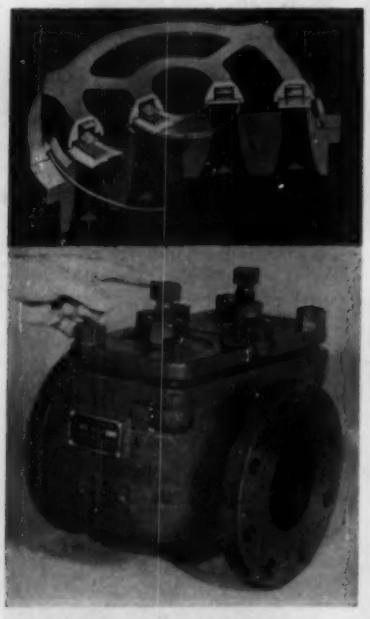
342 Pump, rotary gear. Bulletin describes pumps to handle liquids of high viscosities at 650 gal./min., 350 lb./sq. in. Sier-Bath Gear & Pump Co.

343 Pumps, selector chart. Bulletin describes eleven types of pumps for handling waste materials from Yeomans Brothers Co.

344 Pump, sump-type. Information from Eastern Industries describes vertically submerged sump-type pump used for corrosive, abrasive, radioactive liquids.

345 Regulator, pressure. Catalog contains details for OPW-Jordan's self-operated, pilot-operated, solenoid-operated, and back pressure regulators.

DEVELOPMENT OF THE MONTH



AIR CUSHIONED VALVE

(Circle 604 on Data Post Card)

A unique air cushion design has been incorporated into a line of check valves from Pennsylvania Pump & Compressor Co. to dampen pulsations and to increase service lifetime.

The valve is designed so that flat, annular discs, guided at the outer periphery, lift against a cushion of air as shown in the top photograph. The valve can be installed in any position and can be inspected easily by removing the valve cover (bottom photograph).

For more information from Pennsylvania Pump & Compressor Co., Circle 604 on Data Post Card.

346 Roller Mills, pneumatic. Brochure describes features, applications of mills from Bradley Pulverizer Co.

347 Seals, mechanical. New Bulletin describing line of mechanical seals available from Garlock Inc.

348 Separator, dust. Bulletin containing performance and selection data for dust separators from the Day Co.

349 Spray Nozzles. Twelve-page Bulletin from Binks Mfg. describes and gives specs for variety of spray nozzles.

350 Steam Traps. Information for new line of thermostatic steam traps from Farris Eng. Corp.

351 Tank, corrosion resistant. Information for epoxy bonded, glass filament wound Poxyglas corrosive-resistant tanks. Black, Sivalls & Bryson, Inc.

352 Tanks, Polycel. Data Folder containing complete information and prices for both wooden and Polycel tanks from Wendnagel & Co.

353 Tubing, polyethylene. Catalog containing dimensions, bursting pressures for tubing from Pyramid Plastics.

354 Vacuum Pumps, mechanical. Bulletin with features, maintenance selection data for vacuum pumps from Consolidated Vacuum Corp.

355 Valve, butterfly. Folder illustrates application of valves for large volume flows. Mason-Neilan.

356 Valve, control. Sixteen-page Catalog presents engineering data for control valves from General Kinetics Corp.

357 Valves, polypropylene. Details concerning corrosion resistant polypropylene gate valves from Vanton Pump and Equip. Corp.

358 Valve, safety-relief. A 28-page Catalog contains design data for liquid and special service safety-relief valves. Farris Eng. Corp.

359 Vibrating Equipment, materials handling. A 68-page Catalog presents description, data, specifications of all Syntron products.

360 Water Generators, high temperature. A 36-page Booklet describes high temperature water systems designed by Babcock & Wilcox.

DEVELOPMENT OF THE MONTH

PLATE-AND-FIN HEAT EXCHANGER

(Circle 603 on Data Post Card)

The manufacture of large dip-brazed aluminum plate-and-fin heat exchangers for industrial and cryogenic service has been made practical with recently installed facilities at the Stewart-Warner Corp.

The exchanger shown above, from the first production run of the new brazing furnace, provides almost 8000 sq. ft. of surface and has dimensions of 18" x 21" x 107". This unit costs between $4000 and $4500. A shell-and-tube exchanger of comparable surface is reported to have a 40-in. diameter, be 16-ft. long, and cost approximately $13,500.

Units as large as 22,000 sq. ft. can be dip-brazed.

For more information from Stewart-Warner Corp., Circle 603 on Data Post Card.

MATERIALS *from page 112*

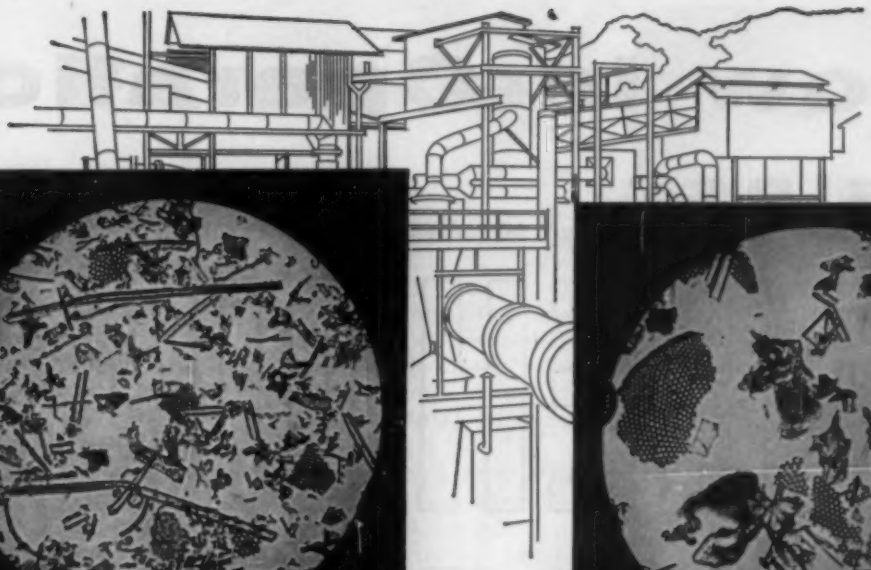
386 Stainless Steel, austenitic. Booklet on sigma phase austenitic stainless steel offered by Electric Steel Foundry Co.

387 Steel-Bonded Carbides. Technical Reprint from Chromalloy Corp. reports results of cermet studies at Sintercast Div.

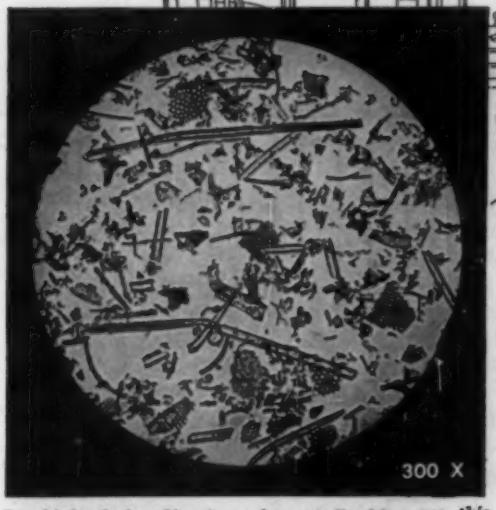
388 Titanium. Technical Bulletin contains properties for alloyed and unalloyed titanium. Data from Nooter Corp.

A.I.Ch.E. Membership

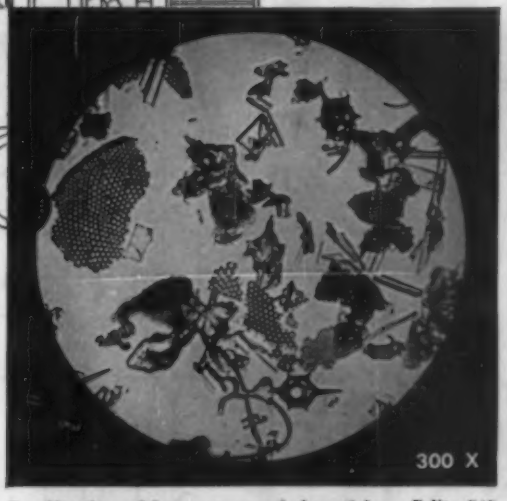
Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 600 on Data Post Card.



Milling and calcining equipment used for all Celite grades.



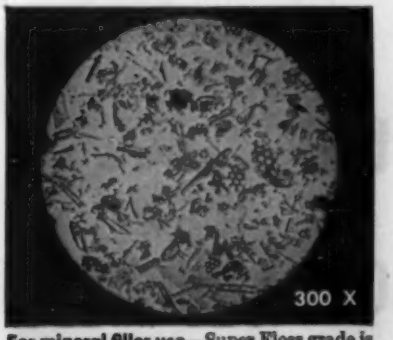
For high-clarity filtration of most liquids—use this specially milled diatomite, Hyflo Super Cel.



For filtration of larger suspended particles—Celite 545 combines maximum clarity plus faster flow rates.

In diatomites, Johns-Manville precision processing works for you

Constant uniformity in every grade of Celite assures consistent results, less down-time



For mineral filler use—Super Floss grade is made up of carefully sized fines air-floated off in the bag house.

Typical J-M bag house equipment.

As THE MICROSCOPE SHOWS, each grade of Celite* diatomite has its own distinctive particle size distribution. Yet no matter where or when purchased, each remains uniform from bag to bag—your assurance of top production results with minimum down-time.

Three examples of flux-calcined Celites are shown here. Hyflo® Super Cel is widely used for filtration in many industries. It has just the right combination of coarse and fine particles to assure optimum clarity and flow rates. Celite 545, with a higher percentage of coarse particles, is used to achieve maximum clarity and faster flow rates with liquids that have larger suspended particles.

Super Floss, one of several bag house grades, has fine particle size distribution. A white powder, it is processed within very narrow tolerances (less than 1% retained on 325 mesh). It is a popular filler in fine products such as silver polishes.

Johns-Manville can precision-produce so many different grades of Celite because it mines the material from the world's largest and purest commercially available deposit. For assistance with specific filtration or mineral filler problems, talk to a nearby Celite engineer. Or write direct to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

JOHNS-MANVILLE

For more information, turn to Data Service card, circle No. 27

Now In Operation

THE FIRST

WAREHOUSE SERVICE

FOR

Tantalum • • Tungsten

Molybdenum • • Columbium

Acidproof Tantalum Chemical Equipment

FANSTEEL

YOUR HANDY GUIDE TO THE FASTEST SERVICE EVER . . .
new Fansteel Warehouse Price and Stock List. Contact your Fansteel representative or write direct to Metals and Fabrication Division.

At Fansteel

Now Order Refractory Metals Just As You Do Steel... from the New Fansteel Warehouse

No more delivery worries. Just phone, wire or write... your request is immediately written up, checked and stamped "WAREHOUSE", which means "In Stock—Rush!" In the warehouse, your materials are selected from waiting shelf stocks, sheared, cleaned, packed, whisked to the shipping dock... and your order is on its way, warehouse to you.

Complete warehouse service: cutting, slitting, other processing; ... technical assistance to save you money, whatever your problem; ... trained, experienced personnel to see that your order is shipped correctly and promptly. And... as always, the best in tantalum, tungsten and other refractory metals from Fansteel... but *faster*.

As Fast, As Dependable As Requisitioning from Your Own Stockroom

Establish regular production schedules and know they'll be kept without heavy inventory investments of your own. Accelerate your R&D schedules with the assurance of experimental quantities whenever you need them. Speed up your prototype or pilot runs with metals right off the Fansteel shelves. Just call Fansteel.

All of These, Now Ready for Shipment

... and more types and sizes added to stock every day—

TANTALUM

Sheet from .005 x 10 x 156" to .125 x 12 x 12"
Foil from .00055 x 10 x Coil to .004 x 10 x Coil
Rod and Wire from .002" to .750"

TUNGSTEN

Sheet from .005 x 6 x 18" to .125 x 7 x 10"
Rod and Wire from .063" to .875"

MOLYBDENUM

Sheet from .005 x 6 x 30" to .125 x 12 x 30"
Foil from .001 x 4 x Coil to .004 x 4 x Coil
Rod and Wire from .010" to 1.500"

COLUMBIUM

Sheet from .005 x 10 x 30" to .125 x 12 x 12"
Rod and Wire from .002" to .250"

COLUMBIUM ALLOYS

Fansteel "80" Metal
Fansteel "82" Metal

ACIDPROOF TANTALUM CHEMICAL EQUIPMENT

Bayonet Heaters
Tapered Condensers
Thermowells
Heat Exchangers

TANTALUM SCREWS, BOLTS, STUDS

TANTALUM TUBING

MOLYBDENUM CRUCIBLES

MOLYBDENUM ELECTRODES

MOLYBDENUM TUBING

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FANSTEEL METALLURGICAL CORPORATION
North Chicago, Illinois, U. S. A.

FANSTEEL

For more information, turn to Data Service card, circle No. 3

chemical feature

New genealogy for epoxides

New family of epoxides being turned out by Union Carbide Chemicals at Institute, W. Va., is based on peracetic acid.

DEVELOPMENT WORK GOING back to 1951 is bearing promising fruit at the Institute, West Virginia, plant of Union Carbide Chemicals with the first commercial production of a whole series of epoxides based on a peracetic acid capacity of some 10 million pounds per year. Process used by Carbide at Institute for production of peracetic depends on incomplete low-temperature oxidation of acetaldehyde, followed by rapid separation of the reaction products, peracetic acid and acetaldehyde. This is a sharp break with the classic route by the reaction of glacial acetic with hydrogen peroxide using a mineral acid catalyst. (Chief U. S. producer up to now has been the Becco Chemical Division of Food Machinery and Chemical).

Advantages claimed for the new peracetic acid process are economics and purity of the product. In the subsequent production of epoxides, the peracetic acid is used as a solution in a non-aqueous inert solvent. This goes far to eliminate the danger in working with a basically unstable material. In addition, the facilities at Institute are equipped with every safety device known to man—and some new ones.

Peracetic-based epoxides

Key feature of Union Carbide's three new commercial-scale "Unox" epoxides 201, 206, and 207, is their basically cycloaliphatic structure, in contrast to the more conventional bisphenol A-based resins.

Type 201, according to Carbide, has a low viscosity at room temperature without use of special solvents or reactive diluents which could downgrade the final properties of the finished plastic. Low viscosity fills voids in castings, reduces bubble formation, and permits better penetration of both glass-fiber laminates and prefilled molds. Being a cycloaliphatic, 201 is less susceptible to the color build-up characteristic of the phenolic groups in bisphenol A-based resins; this makes possible plastics with low initial color and resistance to discoloration from ultra-violet light, heat, and air oxidation. Applications seen are electrical and electronic components, encapsulation, tooling coatings, laminates and adhesives.

Reactive diluent

Type 206 epoxide is said to be an excellent reactive diluent for epoxy resins derived either from the new "Unox" epoxides, or from the bisphe-

continued on page 120

Properties of Unox Epoxides

Unox Epoxide 201

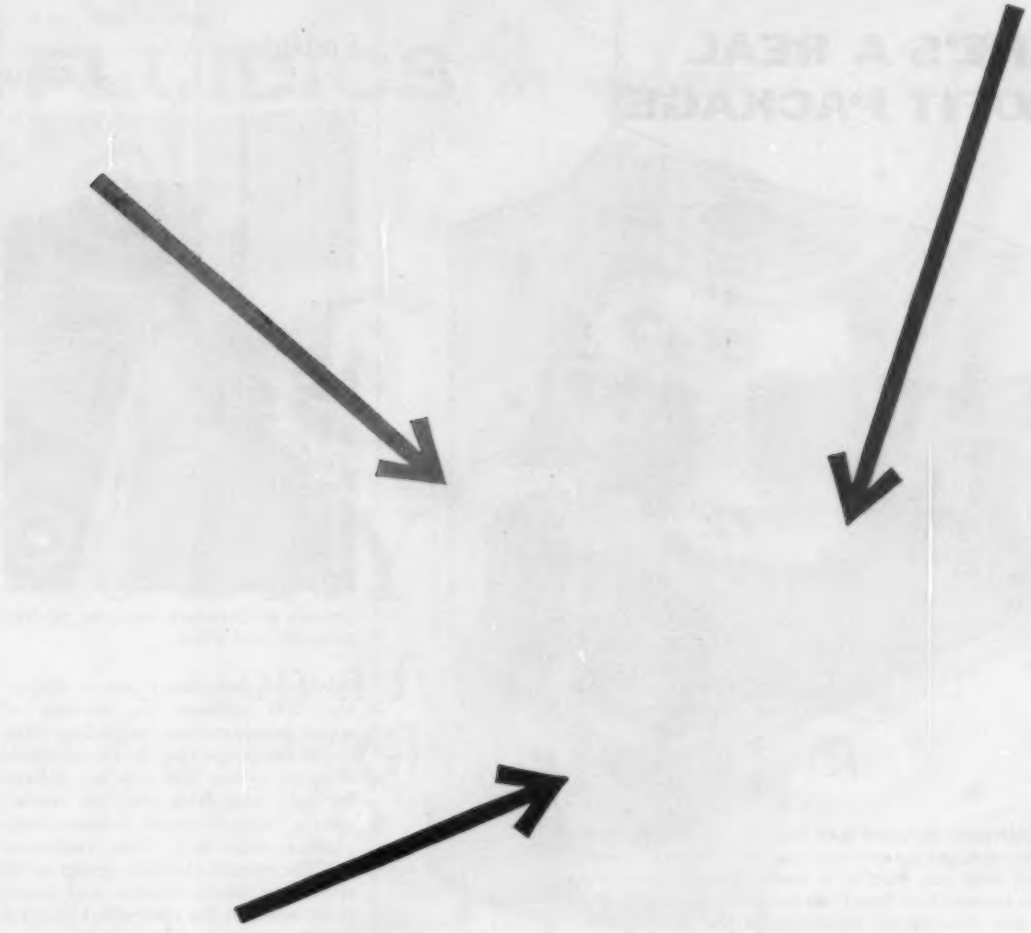
Molecular Weight	280.35
Specific Gravity at 20/20°C.	1.121
Coefficient of Expansion at 20°C.	0.00035 per °C.
Boiling Point at 5 mm. Hg.	215°C.
Pour Point	30°F.
Solubility in Water at 20°C.	0.3% by wt.
Solubility of Water in, at 20°C.	1.8% by wt.
Viscosity at 25°C.	1810 cps
Refractive Index, n_D at 20°C.	1.4920
Flash Point (open cup)	310°F.

Unox Epoxide 206

Molecular Weight	140.18
Specific Gravity at 20/20°C.	1.0986
Weight per gallon at 20°C. lbs.	9.11
Coefficient of Expansion at 20°C.	0.000079 per °C.
Coefficient of Expansion at 55°C.	0.000081 per °C.
Boiling Point at 760 mm. Hg.	227°C.
Flash Point, open cup tester	235°C.
Vapor Pressure at 20°C.	0.1 mm. Hg.
Reid Bomb vapor pressure, 100°F.	Less than 1 psi absolute
Freezing Point	Sets to glass below –55°C.
Solubility in Water at 20°C.	18.3% by wt.
Solubility of Water in, at 20°C.	9.5% by wt.
Viscosity at 20°C.	7.77 cps.
Refractive Index, n_D at 20°C.	1.4787
Epoxide Equivalent (grams resin containing one gram equiv. of epoxide)	74-78

Unox Epoxide 207

Molecular Weight	164.21
Appearance	White crystalline powder
Density at 25°C.	1.331 gram/ml.
Melting Point	184°C.
Solubilities at 25°C. in:	
Water	1.4 wt. %
Acetone	44.7 wt. %
Benzene	48.4 wt. %
Ethyl Ether	18.7 wt. %
Heptane	1.7 wt. %
Methanol	18.6 wt. %
Carbon Tetrachloride	23.1 wt. %



How to know a good thing when you can't see it

Process gases, unlike many other raw materials and intermediates, can't often be seen. But you can always tell where they are used by the way things happen . . . for more and more of these gases are being considered as basic utilities for new or improved chemical processes.

The chemical industry today takes advantage of a wide array of gases produced or purified by low temperature techniques. These include oxygen, nitrogen, argon, synthesis gas, ethylene, methane, HCl, CO . . . and most recently, liquid hydrogen and liquid helium. Air Products is supplying many of them in tonnage quantities to process plants of many types across the nation . . . delivers gaseous or liquefied forms to each customer in the way that suits him best—from a generating plant right at the point of use, or hauled in from a central plant.

Exciting new prospects loom for the chemical industry through continuing developments by Air Products researchers. We're ready with facts, figures and recommendations that should be profitable to you. Air Products, Inc., Allentown, Pa.

Air Products
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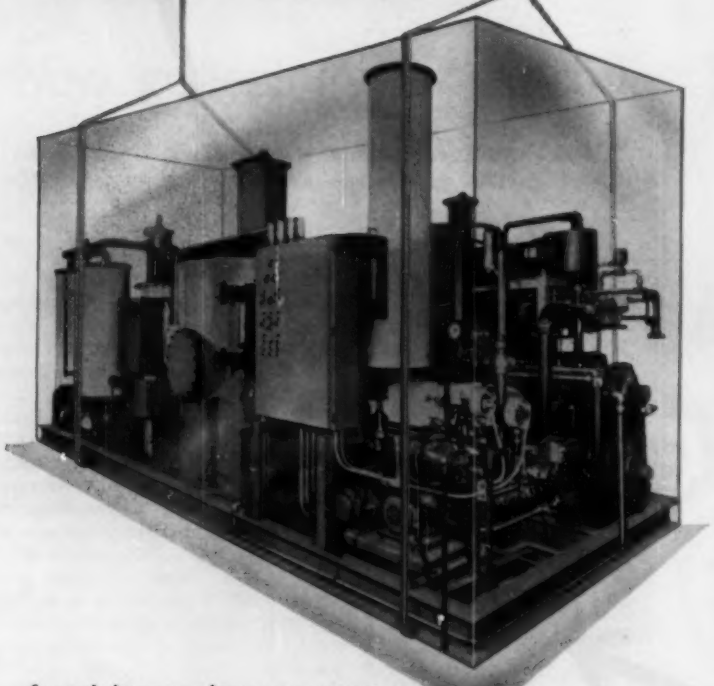
For more information, turn to Data Service card, circle No. 13

For more information, turn to Data Service card, circle No. 149

HERE'S A REAL PROFIT PACKAGE



for minimum volume gas users . . . a [illegible] base, completely packaged gas generator that will produce all the gas you want, when you want it, at lowest possible costs. Even minimum gas users have found they can amortize the cost of an efficient Gas Atmospheres system over a few short months.

Gas Atmospheres builds factory assembled and tested packaged units for the production of reducing, nitrogen, carbon dioxide, hydrogen, inert and annealing atmospheres for use in the metal, food, petroleum and chemical industries—from 50 cfh to 50,000 cfh. If you use gas why not make certain you have the most efficient operation possible. Call in your Gas Atmospheres engineer today or write direct to *Gas Atmospheres, Inc., 3855 West 150th Street, Cleveland 11, Ohio.*

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For more information, turn to Data Service card, circle No. 58

Epoxides

from page 118

Catwalk at Carbide's Institute, W. Va., peracetic and plant.

nol-A-epichlorhydrin types. A diepoxide, 206 reduces the viscosity of epoxy resins without degrading other important properties. In the synthesis of epoxy resins, 206 acts as a solvent for solid anhydride and, on heating with a catalyst, reacts to form tough plastics with high heat resistance.

(The epoxycyclohexan group in the epoxide is reactive under acid conditions, whereas the epoxyethyl group is reactive under basic conditions).

High-temperature properties

Type 207, says Carbide, forms epoxy plastics with good high-temperature physical and electrical properties. It can be converted readily to a "B" stage resin in either a solvent or dry powder form; a shelf life of more than six months is claimed. Such stable "B" stage resins are suited for impregnating glass fibers and for subsequent lamination. Other applications include adhesives for grinding wheels and brake linings, molding, fluidized-bed coating, and high-temperature encapsulation and tooling. Future applications are also seen in plasticizers, protective coatings, and a variety of plastics.

Stepped up research on fluorine polymers, thermally stable fluids, and refractory metals at Allied Chemical has dictated an expansion which will double the lab facilities of its General Chemical Division near Morristown, N.J. Construction of the additional facilities is due to be completed at the end of 1961.

◀ Tear Here for Filing

FLUIDICS* AT WORK

10-DAY DELIVERY

on a full line of Pfaudler Glasteel reactors

"Off-the-shelf delivery" is our term for these completely assembled lab, pilot plant and production-size Pfaudler® Glasteel reactors. All are pre-stocked for a quick, ten-day delivery after receipt of your order.

Check your requirements against these specifications:

Pfaudler "P" Series Reactors

30-gallon (30 p.s.i. internal); 1½ h.p. motor, agitator speed 50-300 RPM

50-gallon (25 p.s.i. internal); 1½ h.p. motor, agitator speed 50-300 RPM

100-gallon (25 p.s.i. internal); 2 h.p. motor; agitator 50-180 RPM

All are clamped-top type, jacketed, and have the following: standard legs, Teflon-enveloped gaskets, 3-blade agitator, non-metallic seal, 2.5TW variable speed drive. *Complete specifications in Bulletin 927.*

Pfaudler "E" Series Reactors

200-gallon, 3TW variable speed drive, 5 h.p. motor, agitator speed 50-165 RPM

300-gallon 4TW variable speed drive, 7½ h.p. motor, agitator speed 32-150 RPM

500-gallon, 4TW variable speed drive, 7½ h.p. motor, agitator speed 32-150 RPM

All are clamped-top type, jacketed, and have maximum internal pressure of 25 p.s.i., code approved for 90 p.s.i. jacket, 3" flanged outlet, standard legs, Teflon-enveloped gaskets, 3-blade impeller, rotary seal, upward deflecting baffles set low, jacket safety valve. *Complete specifications in Bulletin 971.*

Pfaudler "RA" Series Reactors

500-gallon, 4TW drive, 3" rotary seal, 5 h.p. motor, 117 RPM

750-gallon, 5TW drive, 3½" rotary seal, 7½ h.p. motor, 90 RPM

1000-gallon, 5TW drive, 10 h.p. motor, 97 RPM

2000-gallon, BH-30 drive, 15 h.p. motor, 120 RPM

All are one-piece, jacketed and have maximum internal pressure of 100 p.s.i., Teflon-enveloped gaskets, 3-blade impeller, upward deflecting baffle set low. *Complete specifications in Bulletin 988.*

Other standard reactors

The standard line of Glasteel reactors ranges from 1 to 4000 gallons with a choice of 29 different models. Normal delivery quoted, except as outlined above.

Write now for the individual bulletins listed and/or for a summary "spec" and price sheet. Address inquiries to our Pfaudler Division, Dept. CEP-70, Rochester 3, N.Y.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

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WEINMAN

the name for dependability in centrifugal pumps

Weinman general service Unipump for top performance from 10 to 2000 GPM

Your chemical processing system is only as good as its pump. And, if you pump from 10 to 2000 GPM there's a Weinman Centrifugal Pump designed to handle the volume with low cost, 'round-the-clock precision.

Designed to handle any pumping job with speed and efficiency, Weinman's single-stage, end-suction centrifugal pumps are also available with special metals for maximum resistance to chemical corrosive action. Hand finishing of the impeller interior combined with a streamlined volute for fast, efficient pumping performance. Simple design and rugged construction affords years of trouble-free service under the toughest conditions. One piece power frame, large steel shaft and oversized ball bearings handle radial and thrust loads easily. Routine maintenance is accomplished quickly. And, in addition, Weinman manufactures a complete line of general service Unipumps for top efficiency in pumping non-caustic liquids.

For complete information on all Weinman Pumps write today. Or, check the Yellow Pages for your nearest Weinman Specialist and get expert advice right on the job.

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290 SPRUCE STREET — COLUMBUS 15, OHIO

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CENTRIFUGAL SPECIALISTS

For more information, turn to Data Service card, circle No. 21

industrial news

Esso Standard Oil and Carter Oil merged into the new Humble Oil & Refining Company. The latest move in a large scale merger program provides that both Esso Standard and Carter will operate as divisions of the Humble Company.

Construction of an anhydrous hydrofluoric acid plant is next on the agenda at Dixon Chemical's Paulsboro, N. J. site. A continuous process developed by Buss, Ltd. Swiss engineering concern, will be used. A survey of research projects in the field of air pollution is now being taken. Questionnaires asking for information have been setn out by ASME to as many groups as possible that were actively engaged in air pollution research during 1959. The survey will include both the organization and the researcher. Groups that wish to be included are asked to contact Austin Heller, chairman, Task Group Air Pollution Research, American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

In the Chicago Sanitary District's new Zimmerman Process sewage sludge disposal Plant, a systems engineering contract has been awarded by Salvo Chemical (Sterling Drug) to Panellit Service Corporation. The contract involves the automatic control of the air-sludge mixture through 4 reactors processing 200 tons a day.

Polypropylene film for packaging applications is now produced commercially by AviSun at its New Castle, Delaware, facilities. The plant makes 10 million pounds a year, film from one through four mils for general packaging use, and sheets from four to twenty mil thickness for thermoforming.

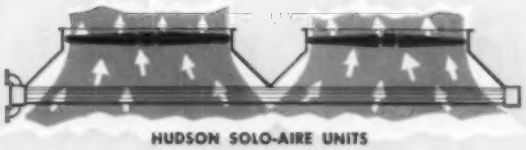
Three major plant acquisitions are expected to boost Century Chemical sales to $10 million. Chemo Puro Manufacturing, Oil & Chemical Terminals and Oil & Chemical Products Asphalt Division, all of Newark, New Jersey, were involved. Also acquired was Chemco Puro AG, European sales organization.

A third major expansion of isocyanate facilities is underway at Mobay Chemical. Company's annual capacity will be raised to over 25 million pounds for tolylene diisocyanate when new facilities are completed in late 1960.

For more information, circle No. 137 ▶

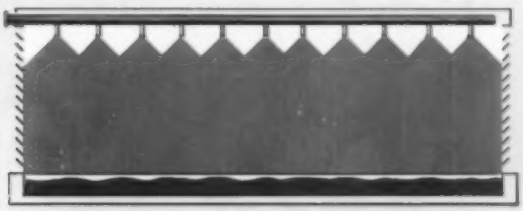
Should Process Plant Cooling Systems Use..

AIR ——



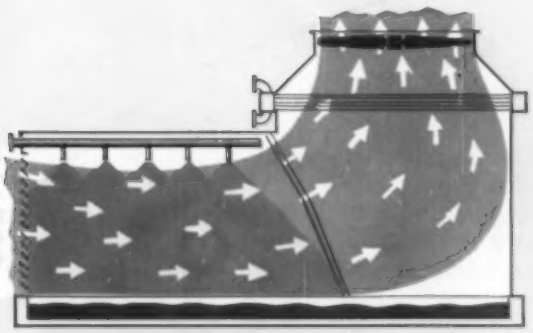
HUDSON SOLO-AIRE UNITS

WATER ——



HUDSON COOLING TOWERS

or a combination of AIR AND WATER ——



HUDSON COMBIN-AIRE UNITS

The answer is found only through comparisons of economics of air, water or a combination of the two for cooling each process stream, and incorporating the results in one integrated cooling system. Factors to be considered include desired effluent temperature of each process stream; summer and winter ambient dry and wet bulb temperatures; availability and quality of water; possibility of public water pollution; space available; and first cost, maintenance cost, and operating cost of equipment.

HUDSON is unique in supplying water cooling towers, Solo-aire units, and Combin-aire units to comprise integrated cooling systems utilizing air and water in economic ratios. With the collaboration of owners' engineers, HUDSON has designed integrated cooling systems for a wide range of process and climatic conditions. Hundreds of HUDSON installations are operating in the United States, Ireland, England, France, Spain, Norway, Saudi Arabia, Pakistan, the Philippines, Mexico, Chile, Peru, Venezuela, and Canada. HUDSON experience, available without obligation in integrating the cooling system with process design, will be most valuable to plant owners if utilized during planning stages.

In early design stages of future projects let HUDSON collaborate with your engineers in selecting the integrated cooling system which best balances capital investment and operating cost for the specific process, climatic and water conditions.

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ENGINEERING PERSPECTIVE
THROUGH A

VENTURI

Venturi tubes were first used for measuring fluid flow. While this application has increased substantially, the use of the Venturi in important unit process operations has increased even more. A Jet-Venturi combination is literally the heart of many important manufacturing processes.

During the first several years of the forty-two year history of our firm, we specialized entirely on steam jet vacuum pumps (ejectors). Many thousands of these are in service throughout the country and in most foreign countries. Our tradename, EVACTOR, is an important word in engineering circles. While steam jet vacuum pumps are still our major item, other applications of Jet-Venturi equipment are increasing constantly. With the exception of closely related products such as barometric condensers, CHILL-VACTORS, and CONVACTOR* systems, all of our activity is directed to the one purpose of making Jet-Venturi units more efficient, more dependable, more economical, and to apply them to an increasing number of industrial applications.

JET REFRIGERATION
JET COMPRESSORS
JET CONDENSERS
JET HEATERS
JET PUMPS
JET MIXERS
JET REACTORS
JET ABSORBERS
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SPECIAL JET VENTURI UNITS

*The CONVACTOR is a dual condensing system for economic and efficient recovery of high boiling components from water vapor.

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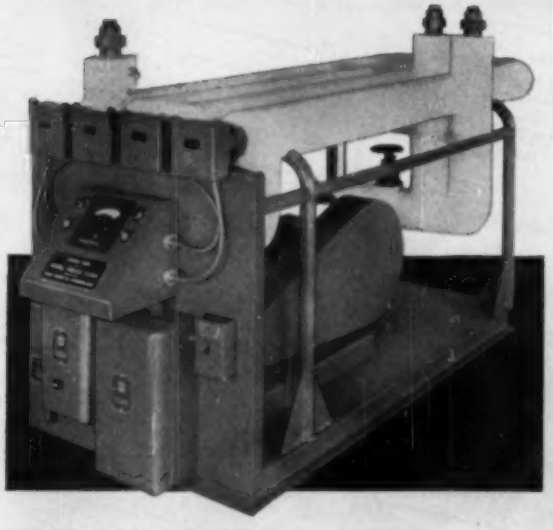
For more information, turn to Data Service card, Circle No. 31

HI-TEMPERATURE LO-PRESSURE

liquid phase heat transfer systems



if

—Your product temperature requirements are high

—You want to avoid high pressure equipment

—You need close temperature control and safe, automatic operation at reasonable cost . . .

. . . . You should consider a space saving, all electric, Merrill Process System. Heating mediums can be Oil, Aroclor® or Dowtherm®.

A twist of the wrist puts these systems into operation—and they will hold fluid temperatures to within ±2°F. within the range of 200-600°F.

Heat exchangers can be factory mounted and piped when a cooling cycle is required.

Dual systems are available having two completely independent circuits with separate control systems providing heating and/or cooling in sequence, simultaneously, or in any combination in the same unit.

Low watt density finned heating elements protect the heating medium and are readily accessible for routine maintenance. Relief valves, limit switches and positive displacement pumps assure safe, dependable operation. An expansion tank, vented to atmosphere, precludes contact of air with the circulating medium and prevents pressure build-up.

All of the Electric Merrill Process Systems have push button operation from a single control center.

Capacity of available systems ranges from 25,000 Btu/hr. to 500,000 Btu/hr. or up to limits of available power. Heating elements wired for 230-3-60 only in Pilot Plant series to 100,000 Btu/hr., and 230,460, or 550-3-60 in larger units. Control circuit is for 110V 60.

Write for Bulletin 597 giving details of the Pilot Plant Series or send us your requirements.

Parks-Cramer Company

FITCHBURG 6, MASS.

For more information, turn to Data Service card, circle No. 42

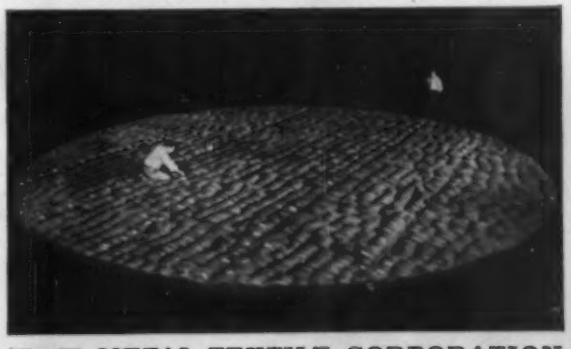
METEX MIST ELIMINATORS

. . . the First name in knitted wire entrainment separators!

FIRST with strip-type construction
FIRST with wound-type construction
FIRST with Hi-Thruput® mesh
FIRST with fiberglas coalescers
FIRST with all-metal coalescers
FIRST with polyethylene
NOW FIRST with Teflon®

Since 1943, when it first introduced knitted wire entrainment separators—Metal Textile has been consistently first in introducing new developments to the field. In response to requests from chemical and processing engineers throughout industry—Metex engineers have utilized new materials...developed special meshes . . . initiated revolutionary techniques to provide low-cost, high-efficiency answers to the most complex entrainment problems. Your specific needs can be similarly solved. Our engineers, backed by the most extensive research and production facilities in the field, will be glad to recommend the type of Metex Mist Eliminator and method of installation best suited to your particular operating conditions. For latest design guides, write or call for Bulletin ME-9: Metal Textile Corporation, Roselle, New Jersey.

38' dia. Metex Hi-Thruput Mist Eliminator for world's largest vacuum pipe still.



METAL TEXTILE CORPORATION

. . . world's largest and oldest producer of knitted wire products

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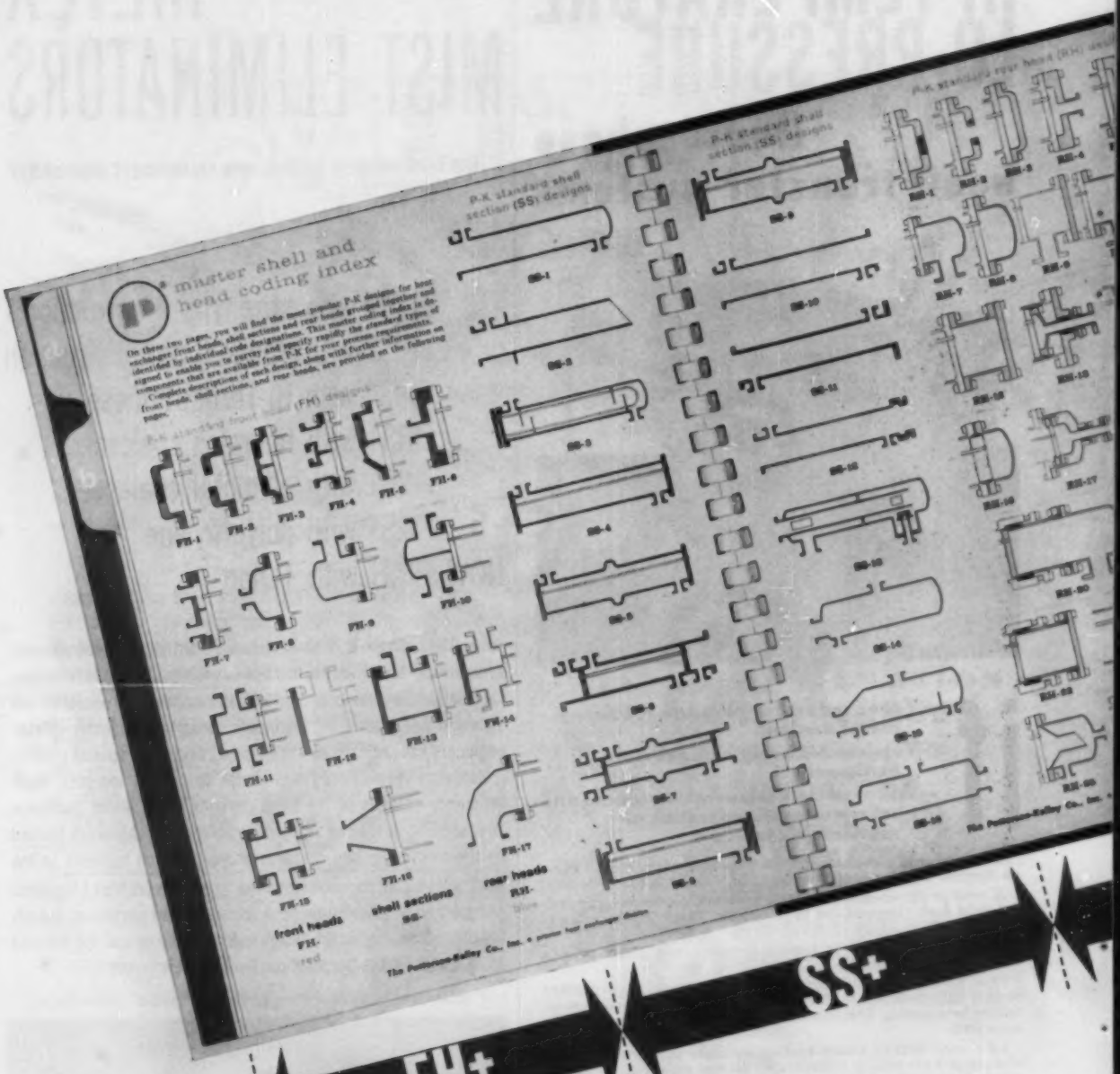
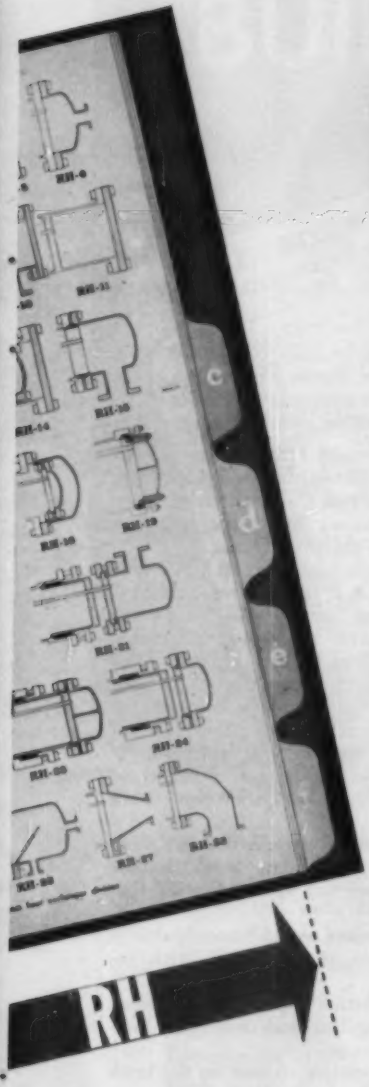
For more information, turn to Data Service card, circle No. 17



FH+ SS+

NEW SIMPLE FORMULA IN P-K HEAT EXCHANGER



AEC using P-K Heat Exchanger. This P-K Heat Exchanger runs 24 hours a day, 5 to 7 days a week, at the Uranium Processing Plant at Weldon Spring, Mo., operated for the AEC by Mallinckrodt Chemical Works. Although placed in operation in April 1958, and handling highly corrosive hydrofluoric acid at temperatures above 300°F., this two-pass shell and tube type unit has never once required maintenance.

Select the *Front Head* you want, from the *FH* group. Add the *Shell Section* you want, from the *SS* group. Add the *Rear Head* you want, from the *RH* group.

Follow these three simple steps and the formula above enables you to select the "designed" heat exchanger that meets your requirements.

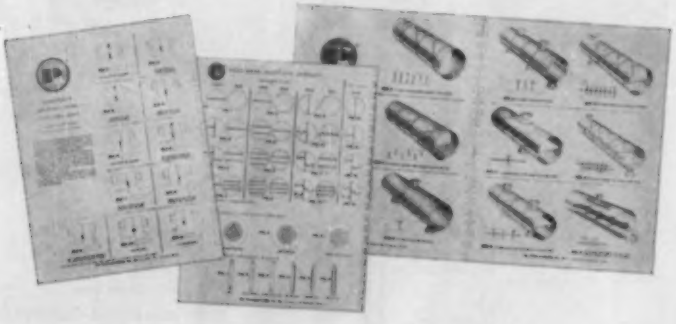
As you can see, the two pages at left from the new P-K Heat Exchanger Manual provide a master coding index. This makes it possible to rapidly survey and specify the standard interchangeable components available from P-K. Succeeding pages treat design features of each component in detail and save you time when you want to determine their suitability for your application.

Suppose, for example you want an exchanger with the following: front head bonnet, multi-pass, radial flanged connections; shell section with straight tube floating head, and pull through removable bundle construction; straight tube floating rear head, pull through removable bundle and shell cover plate, with multiple pass. Consult your P-K Manual, pages b-1 through b-18. Then specify FH-10+SS-10+RH-14.

Clear, parallel picturization of standard gasket joints, tube pass partitions, shell baffles and other components simplifies the underlying details of designs.

Other sections of the manual standardize terminology, review fundamentals of heat transfer and design, even discuss economic considerations.

Since available copies of the new P-K Heat Exchanger Manual are limited in number, they are reserved primarily for those in the process industries who can most profitably use the information. If you design or specify heat exchangers, write us on your company letterhead, outlining briefly the areas of your interest. A few copies are available to students and non-technical personnel at a nominal charge. The Patterson-Kelley Co., Inc., 115 Burson Street, East Stroudsburg, Pa.



MANUAL HELPS YOU SELECT YOUR HEAT EXCHANGER

Patterson Kelley
Heat Exchanger Division

equipment feature

New design chlorine bleaching tower

Increased brightness, reduced color reversion, decreased cost of chemicals demonstrated by new Dorr-Oliver tower at Potlatch Forrests, Inc., Lewiston, Idaho.

FIRST INSTALLATION of a new Dorr-Oliver bleaching tower design is in successful operation at the pulp mill of Potlatch Forrests, Inc., in Lewiston, Idaho.

The standard bleaching tower unit offered by Dorr-Oliver (Figure 1), consists of external heater-mixer, thick stock pump and ClO_2 mixer, an inner "upflow" tower with a "plumb-bob" distributor, and an outer "downflow" cylinder including dilution, neutralizing, circulation, and discharge equipment. The compact concentric design, claims Dorr-Oliver, eliminates need to mount equipment above the tower, while the low diameter: height ratio limits the surface area and, as a result, reduces the heat loss.

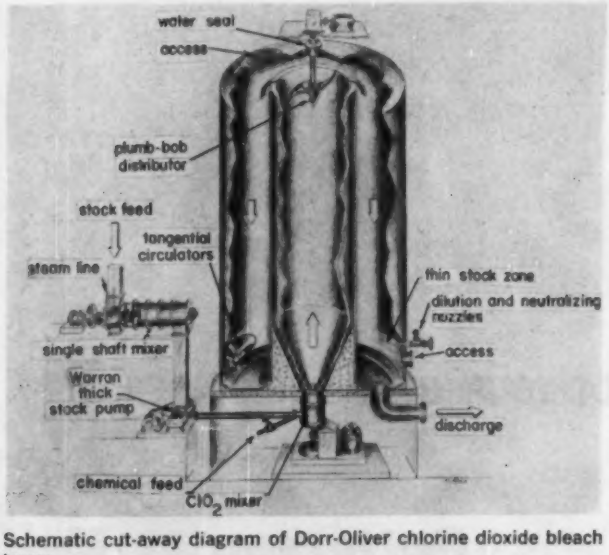
Operation

Chlorine dioxide is introduced into the pulp at the base of the tower, where the mixture is kept under hydrostatic pressure for approximately an hour. By the time the pulp is distributed over the circular top weir, 90% of the chlorine has been consumed, thus reducing ClO_2 losses and puffs. The "plumb-bob" distributor spreads the pulp uniformly into the annular downflow section.

Retention time in the downflow section.

Retention time in the downflow phase can be varied to meet changes in pulp and tonnage requirements, and to provide continuous control of the reaction. Dilution, neutralization, and repulping are carried out in the bottom zone of the annular downflow section. Retention time and other controlling factors in the treatment can be held constant for almost all the pulp through draw-down, in the event of shut-down or change of pulp grade.

The new design is being offered by Dorr-Oliver in capacities from 100 to 800 tons per day. It is stated to be suitable for erection either indoors, or out, and to be fully compatible with normal flow sheets for kraft production systems incorporating one or more chlorine dioxide bleaching stages.



Schematic cut-away diagram of Dorr-Oliver chlorine dioxide bleach tower.

Potlatch Forrests installation

The Problem—Increased bleaching requirements at the Potlatch Forrests mill demanded increased retention time in the chlorine dioxide stage: engineering considerations set this retention time at 5 hours. Five hours retention time for 700 tons per day of pulp required an exceedingly large tower. A high-density upflow tower was designed, using a conical inlet with a 60° included angle. Going to the maximum practical diameter of 20 feet, the tower was 130 feet high, excluding the launder arrangement at the top. Difficulties, however, were many:

- It was not certain that an existing thick stock pump would handle 700 tons per day against the 130 foot head;
- The tower would be costly due to the amount of steel and brick involved;
- Foundation requirements involved distributing the load over a 30 foot-diameter base;
- Compressive stresses on the brick lining were considerable;
- Erection would be difficult since the top of the tower could not be reached by the existing yard crane.

A conventional upflow-downflow chlorine dioxide bleach tower was also considered. By maintaining a tower diameter in the upflow section of approximately 10 feet, there was no question about a uniform flow up the pre-retention tube. The downflow tower would be 20 feet in diameter, the maximum to assure relatively uniform discharge by a conventional circulator and dilution nozzle arrangement. One advantage of this design would be that the tower could rest directly on the foundation pad; a sec-

continued on page 130

BUILD YOUR OWN DeZURIK VALVE!

With this wide choice of materials — valve body and resilient plug facing — DeZurik Valves can be "custom-made" for almost any chemical service line. Whether it's corrosive or erosive . . . . a liquid, slurry or gas . . . . chances are you can "build" a DeZurik Valve to handle it better — longer!

In addition to the materials listed above, DeZurik Valves are also available with *Hard Rubber Lining* or *Soft Rubber Lining* for extra resistance to abrasive or corrosive services, or *Plastic Coated* for low-cost corrosion resistance.

DeZurik Valves are available in sizes ½" thru 24" and with a complete line of automatic actuators. For more details, see the DeZurik representative in your area, or write

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For more information, turn to Data Service card, circle No. 147

Bleach tower

from page 128

ond that the dilution zone in the base of the tower would provide a retention period where the neutralizing agent could be added, prior to pumping the stock to the washer.

However, this tower also required an over-all height of approximately 130 feet. Estimated lining costs were even more than for the first tower design considered.

The solution

A modification of the new Dorr-Oliver standard design has proved successful in solving the special problems posed by the previously considered designs:

- An upflow center tower, 13 feet in diameter, with conical inlet section, does not pose channeling problems;
- An inner tower height of 65 feet is within the range of the existing thick stock pump;
- The over-all tower height of 78 feet permits use of existing yard equipment for erection and maintenance.

The upflow inner tower of the D-O installation at Potlatch Forrests provides one full hour of retention for a rate of 700 tons per day; this reduces the partial pressure of chlorine dioxide in the vapor phase at the top of the tower. A distributing device transfers stock to the outer downflow tower. Inside diameter of the downflow outer tower is 30 feet and, when operated at its normal level, provides a full 4-hour retention time above the dilution zone. Retention time can be adjusted by controlling the pulp level.

The bottom of the tower is equipped with 10 standard dilution nozzles, and circulators for repulping.

Bleaching at Potlatch Forrests

Stock at 12% consistency is fed to an Impco double-shaft heater-mixer, and raised to a temperature of 160-170°F. The stock discharges from the heater-mixer into an Impco thick stock pump. Chlorine dioxide bleach liquor at a concentration of 10.0-10.25 grams per liter is added to the stock before it enters an Impco vertical, double-shaft mixer. After thorough mixing, the stock is delivered to the D-O bleach tower.

Before the stock enters the tower, however, a small amount of 5% caustic is added to adjust the pH before dilution to 3.5. The final pH of the stock delivered to the washer is con-

continued on page 132

MATHESON

Compressed Gas Notes

Uses of Anhydrous Ammonia in the Laboratory

Ammonia is a highly reactive, associated, and stable chemical decomposing at atmospheric pressure at temperatures of 450-500°C. Extensive references to its reactions are available in the technical and patent literature.

At room temperature and atmospheric pressure, ammonia is a colorless, alkaline gas, lighter than air, having a pungent odor. It is readily liquefied and it is shipped in steel cylinders as a liquefied gas (B.P.-33.35°C.) under its own vapor pressure of 114 p.s.i.g. at 70°F.

As a liquid, ammonia, like water, is an important ionizing solvent and has been one of the most comprehensively studied nonaqueous solvents.

Ammonia is toxic, but its odor and irritating action on the eyes provide ample warning of its presence. It is best handled in a hood with forced ventilation, using appropriate protective equipment.

Some of the important uses of gaseous and liquid ammonia in organic and inorganic chemistry are as follows:

Uses in Organic Chemistry

Liquid or gaseous (in solvents) ammonia is widely used in the ammonolysis of esters, acid anhydrides, and acyl and sulfonyl halides and in the replacement by ammonolysis of halogen, hydroxyl, sulfonic acid, and labile nitro groups; amides and amino compounds are formed depending on the compound being reacted. Liquid ammonia is also used as a solvent for alkylations and dehydrohalogenations with sodamide. Aldehydes and epoxy compounds add ammonia directly. Aldehydes and ketones are converted to amines by reductive amination. Aldoses are converted by ammonia into aldoseamines.

Uses in Inorganic Chemistry

The alkali metals dissolve readily in liquid ammonia in the absence of catalysts; the alkaline earth metals also dissolve but to a smaller extent. Ammonium salts, free elements, hydrides, halides, and cyanides, oxides and sulfides undergo reduction by metals in liquid ammonia. Acid-base reactions, involving ammonium salts, and amides, imides and nitrides, occur in liquid ammonia. Many inorganic salts undergo ammonolysis in gaseous or liquid ammonia.

Ammonia Cylinders

Cylinders containing 15 lbs. or more of ammonia are equipped with eductor tubes to allow withdrawal of liquid ammonia by placing the cylinder in a horizontal position with the valve outlet up.

Gaseous ammonia is obtained by withdrawing the contents with the cylinder standing in a normal, vertical position. Small cylinders containing less than 15 lbs. of ammonia must be inverted to obtain liquid.

Controls

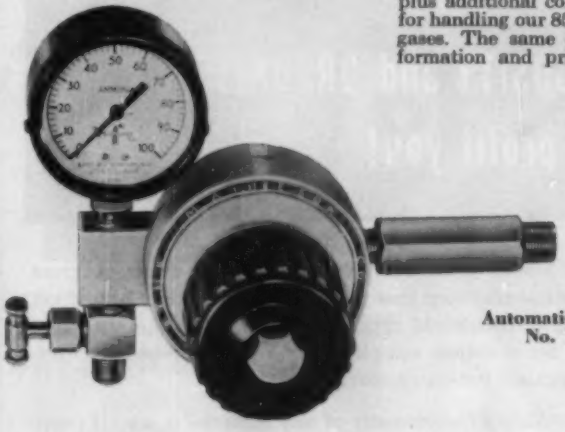
The Matheson Company, Inc. supplies a variety of controls and accessories to make the handling of either gaseous or liquid ammonia safe and simple.

Automatic regulator No. 12-240 will allow the controlled delivery of gaseous ammonia over a pressure range of 2-50 p.s.i.g., and higher, if necessary. This regulator is constructed with a sturdy aluminum body, stainless steel internal parts, and a butyl rubber diaphragm for sensitive pressure control.

Manual flow control of either liquid or gaseous ammonia can be accomplished by the use of a No. 51-240 valve available with a variety of outlet types to simplify hook-ups to flexible tubing or pipe. Valve outlet No. 240 is described in our Cylinder Valve Outlet Bulletin, available on request.

Special reinforced, heavy duty, neoprene lined hoses for use specifically with ammonia are available in different lengths.

Send for the new Matheson Gas Price List describing the above equipment, plus additional controls and accessories for handling our 85 different compressed gases. The same catalog gives full information and prices on all 85 gases.



Automatic Regulator No. 12-240

The Matheson Company, Inc., P.O. Box 85, E. Rutherford, N.J.

Please send the following:

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☐ Wall Chart: "Safe Handling of Compressed Gases"

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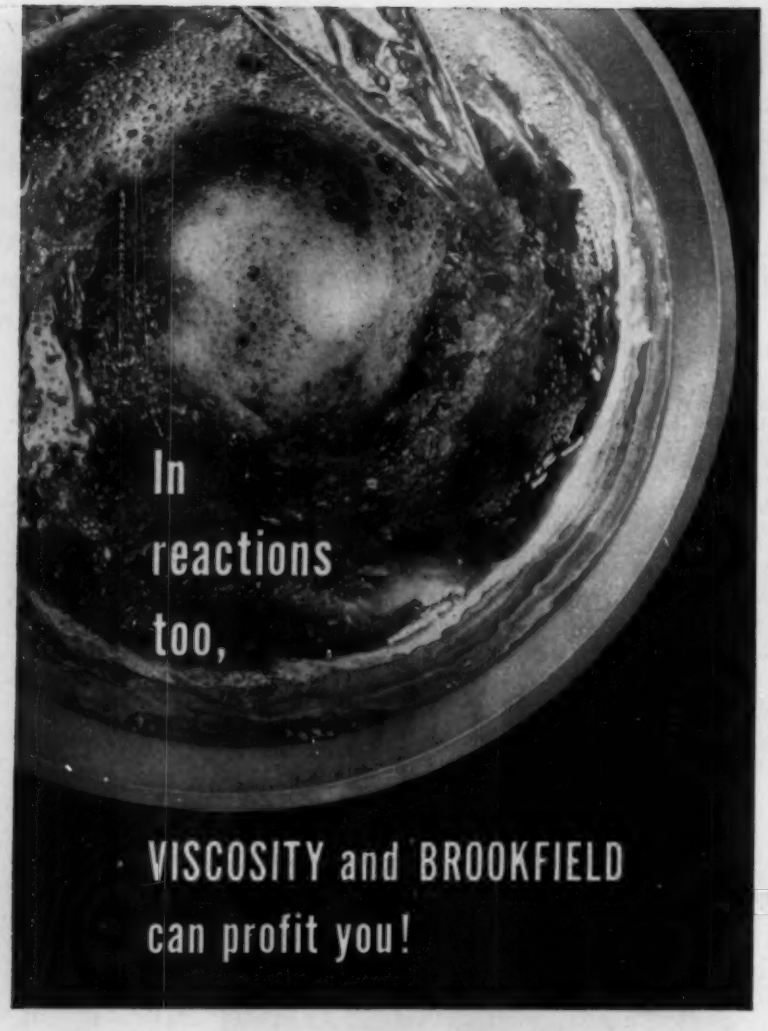

It's true. In-process viscosity measurement is the most direct progress report of many chemical reactions that you can obtain. In polymerization reactions, for example, Brookfield process-mounted Viscometran units eliminate the need for constant sampling, assure greater product uniformity and guard against run-away reactions.

Like color, pH and stability the *viscosity* of any material is a vital property, a fundamental measurement, which can be easily and accurately evaluated and controlled with low-investment Brookfield instrumentation.

If you would like to know more about the profitable role of viscosity control in your processes, write today for complete technical information. There is no obligation.

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ENGINEERING LABORATORIES, INCORPORATED

STOUGHTON 38, MASSACHUSETTS

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Bleach tower

from page 130

trolled at 7.0 by caustic added with the ring dilution water.

Chlorine dioxide consumption averages 0.6% or 12 pounds per ton of pulp. Final brightness is 86-88 GE. According to Potlatch engineers, an increase in the ClO_2 bleach retention time from 1½ hour to 5 hours, coupled with use of the new design tower, has resulted in increased brightness, reduced color reversion, decreased cost of chemicals.

NOTE: *Details of the tower installation at Potlatch Forrests, Inc. are from a paper by D. T. Keller, Potlatch Forrests, and W. Christiani, Dorr-Oliver, Inc., presented before the Paper Industry Management Association at San Francisco, June 8, 1960.*

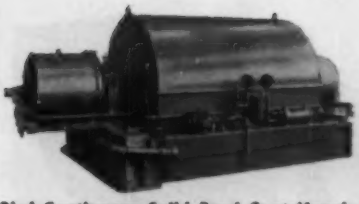
A new urea plant in Portugal will produce 40,000 metric tons annually. Under an agreement between Montecatini and Uniao Fabril do Azoto of Portugal, the plant will be constructed near Barreiro, on the Tagus River. Engineered by Kellogg, the facility will incorporate the most up-to-date technology of the Fauser-Montecatini process, total recycle in the liquid phase. This allows full utilization of the ammonia feed in the formation of urea.

A new polybutene unit at Standard Oil of California's Richmond refinery will double Oronite Chemical's capacity. Growing demand in the lubricating oil additive field is a factor in the expansion of two existing plants at the refinery, will make Oronite one of the world's largest producers of polybutene, the company says.

A broader line of alkylated phenol will be produced at Koppers' expanded Oil City, Pa., plant. Among the new products are: paratertiary butyl phenol, paratertiary amyl-phenol, amyl-phenol, dibutyl phenol.

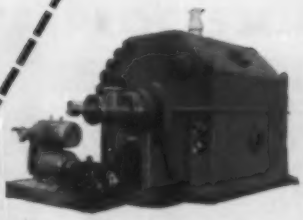
A 3,500 barrels a day naphtha hydrodesulfurization unit to be erected at British American Oil's refinery at Calgary, Alberta, Canada, will be engineered by the Fluor Corp. Completion is slated for September.

Production of pyromellitic acid and pyromellitic dianhydride has started at Du Pont's multi-million pound a year unit at the Repauno Works, Gibbstown, N.J. Commercial production has made possible price reductions on PMA from $2.50 to 85¢ a pound, and from $3 to $1 a pound for PMDA.



Bird Continuous Solid Bowl Centrifugals come in 7 sizes, each with a great many design variations to meet a wide range of product and process needs. Shown is the largest (54 in. bowl dia.) for ton-a-minute delivery of well dewatered solids.

Bird-Humboldt Oscillating Screen Centrifuges dewater coarse solids (+65 mesh) with almost no degradation or loss of solids. Screens last thousands of hours. Power cost is extraordinarily low (0.2 KWA input per ton of dried solids).

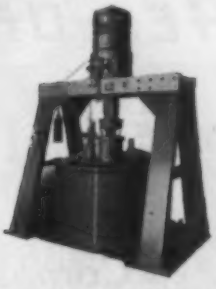


Bird-Young Rotary Drum Vacuum Filters are of unique design providing several times the usual capacity per foot of filter area, super-efficient wash, sharp wash separations and fume-tight operation when desired.

SIX WAYS TO SEPARATE SOLIDS FROM LIQUIDS

Which one is best for you?

Bird Pressure Leaf Filters provide rugged construction, large sustained filter area, high rate of flow, high working pressures (up to 75 psi standard, 250 psi special). They are custom built for the job — of corrosion resistant alloys or with special linings; insulated; steam jacketed; in a wide range of sizes.



Bird Suspended Batch Centrifuges are for heavy duty service. They come with 26", 40" or 48" basket, perforate or imperforate. All kinds of auxiliaries are availabe, also fume-tight or explosion proof construction.

Bird-Prayon Tilting Pan Rotary Vacuum Filters combine great capacity range with most effective, multistage washing, constant high output and minimum maintenance cost. They are ideal for handling materials that cannot be picked up by a drum or disc filter.

Let the *Bird Research and Development Center* help you find out. Here, under one roof, is a completely equipped and staffed, pilot-scale test plant concentrating exclusively on solid-liquid separating problems.

Bird builds the most comprehensive range of solid-liquid separating equipment, is therefore in a position to fit the machine to the job — not the job to the machine.

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TYPE R Removable-Header WATER COILS

- Complete Drainability
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- High Heat Transfer

Completely drainable and easily cleaned, Aerofin Type "R" coils are specially designed for installations where frequent mechanical cleaning of the inside of the tubes is required.

The use of 5/8" O.D. tubes permits the coil to drain completely through the water and drain connections and, in installations where sediment is a problem, the coil can be pitched in either direction. The simple removal of a single gasketed plate at each end of the coil exposes every tube, and makes thorough cleaning possible from either end.

The finned tubes are staggered in the direction of air flow, resulting in maximum heat transfer. Casings are standardized for easy installation.

Write for Bulletin No. R-50

AEROFIN CORPORATION

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Aerofin is sold only by manufacturers of fan system apparatus. List on request.

For more information, turn to Data Service card, circle No. 127

industrial news

Fertilizer output up at Olin Mathieson, Calspray

Addition to high analysis unit boosts Olin Mathieson production by 40%. $5 million complex on-stream at Calspray.

PRODUCTION IN ONE of the world's largest high-analysis fertilizer plants began when a newly constructed addition to Olin Mathieson's Pasadena, Texas, unit went on stream. The $1,500,000 addition gives the facility a capacity of more than a ton of pelletized fertilizer a minute—a 40 percent gain over former output.

Completion of the added unit reflects the recent growth in use of high-analysis fertilizers. In 1949, they accounted for 12 percent of all fertilizer used. Last year in the United States 41 percent of a total of 25 million tons of fertilizer was high analysis. This included 550,000 tons of the ammonium phosphate type.

High analysis fertilizer pellets are being dried at the rate of 150 tons an hour at Olin Mathieson's Pasadena plant.

Based on present calculations, any mixed fertilizer with a plant nutrient content totalling 30 percent is considered high analysis. So that a fertilizer with say 12-24-12 would be considered high analysis, while 5-10-5 would not. (The above code represents the nitrogen, phosphate and potash percentages per hundred pounds, always in that order.)

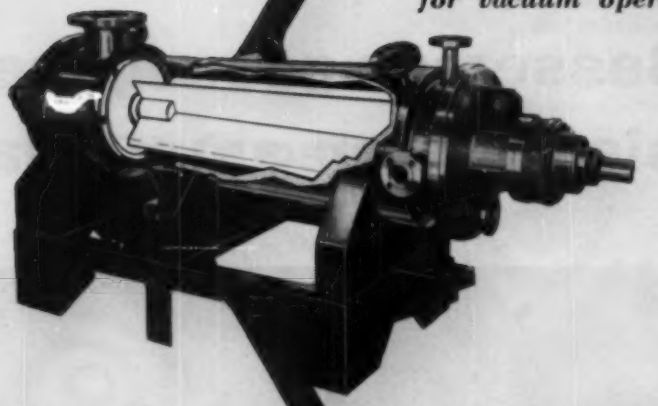
Several new grades of high analysis ammonium phosphate fertilizer (trade-named Ammo-Phos) have been added in the present plant expansion at Olin Mathieson. Among them are: 15-15-15, 16-48-0, 14-28-14, 7-28-28, 9-36-18, 13-39-13, 12-24-24. These grades were developed for a wide variety of crop and soil conditions.

continued on page 138

ONLY KONTRO

Makes BOTH these HEAT-EXCHANGE PROCESSORS

The centrifugally-wiped, thin-film AJUST-o-FILM for vacuum operations with vapor removal

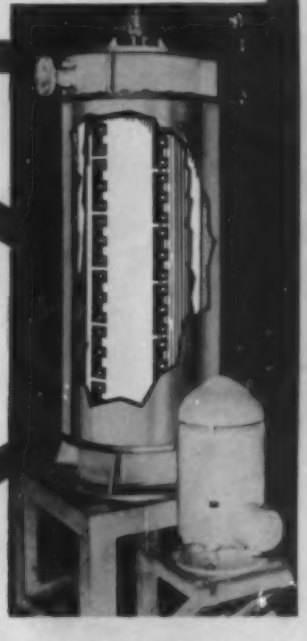


- **UNUSUALLY HIGH HEAT TRANSFER** for such operations
- **QUICK THROUGHPUT TIME,** ideal for heat sensitive products. Throughput can be varied as desired from a few seconds by "ajusting" blade clearance and feed rate
- **HIGH or LOW VISCOSITY** materials processed in a single, positive short-time pass
- **UNLIMITED CONCENTRATION,** distillation or evaporation
- **ROTOR BLADE CLEARANCE "AJUSTED"** easily through exclusive tapered* design, for highest quality, thermal and power performance
- **NO "BURN-ON"** because assured turbulence throughout prevents dry spots

Foreign Patents Pending

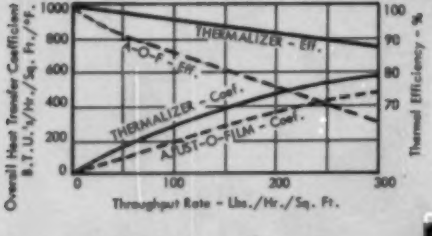
*Patents Issued and Pending

and the scraped-surface THERMALIZER for heat exchange or chemical reactions under pressure, with no vapor removal



- **HIGH HEAT TRANSFER** with either high or low viscosity products
- **SHORT HOLD-UP TIME,** ideal for heat sensitive materials. Hold-up time controlled by regulating feed rate
- **NO "BURN-ON"** because of unique positive scraping action
- **SMOOTH HEAT TRANSFER WALL,** usually honed, and chrome-plated for wear resistance, when practical
- **EXTERNAL COOLED ROLLER BEARINGS** and lubricated double face seals, pressurized when necessary

Advantages of Scraped Surface Thermalizer for heating aqueous materials without evaporation



Both these KONTRO Heat Exchange Processors achieve wide throughput variations with equal quality. External cooled roller bearings and lubricated double mechanical face seals at both ends of rotor. Either machine is available for horizontal or vertical mounting, and for varying capacities and temperatures. Manufactured to your specifications in any designated material of construction.

Write for information on relative performance of horizontal and vertical wiped film processors

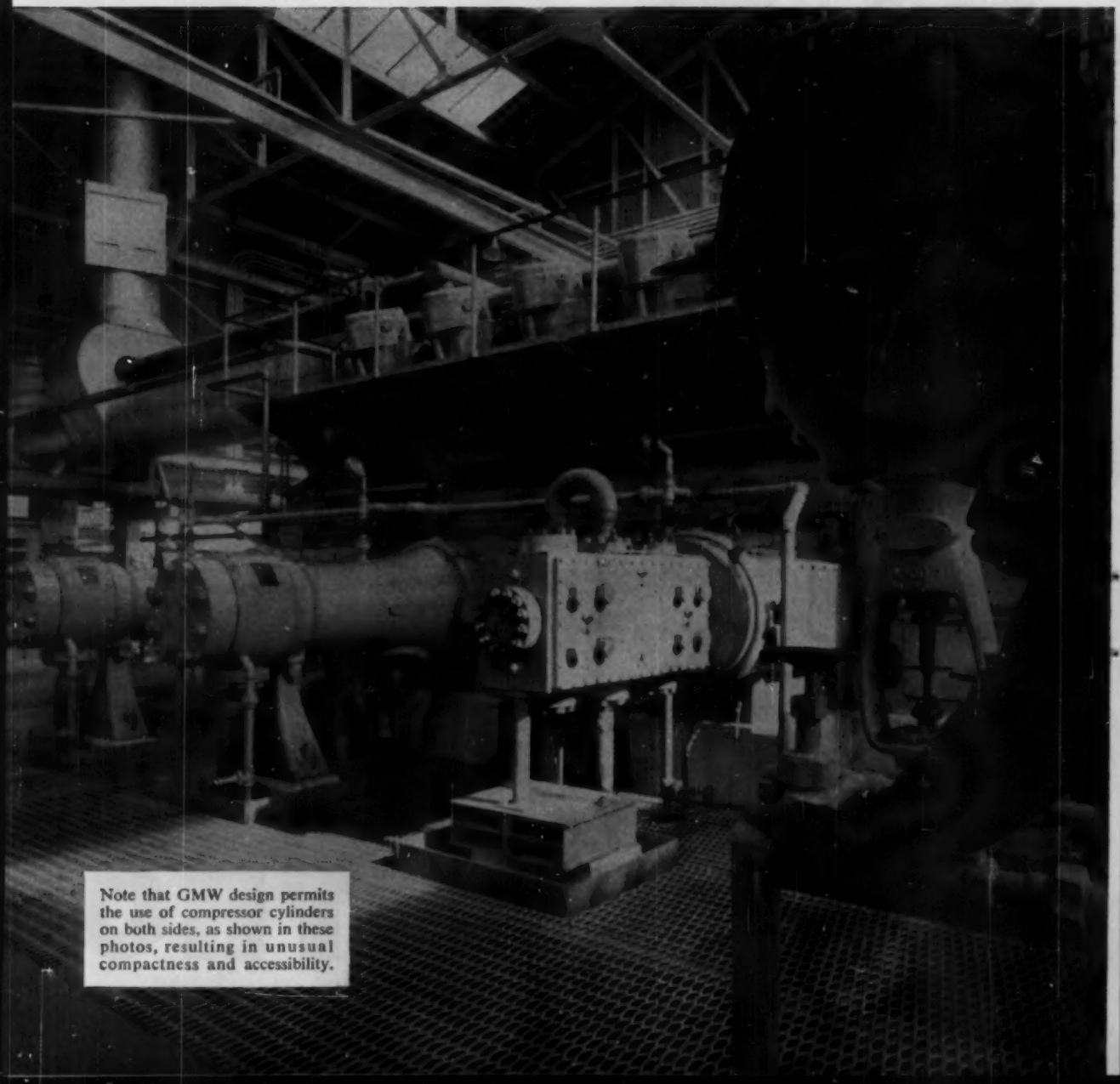
The Kontro Company, Inc.
Petersham, Massachusetts

KONTRO

For more information, turn to Data Service card, circle No. 124

Report from American Cyanamid, Fortier Plant...

How Cooper-Bessemer gas engine boost synthesis gas for ammonia



Note that GMW design permits the use of compressor cylinders on both sides, as shown in these photos, resulting in unusual compactness and accessibility.

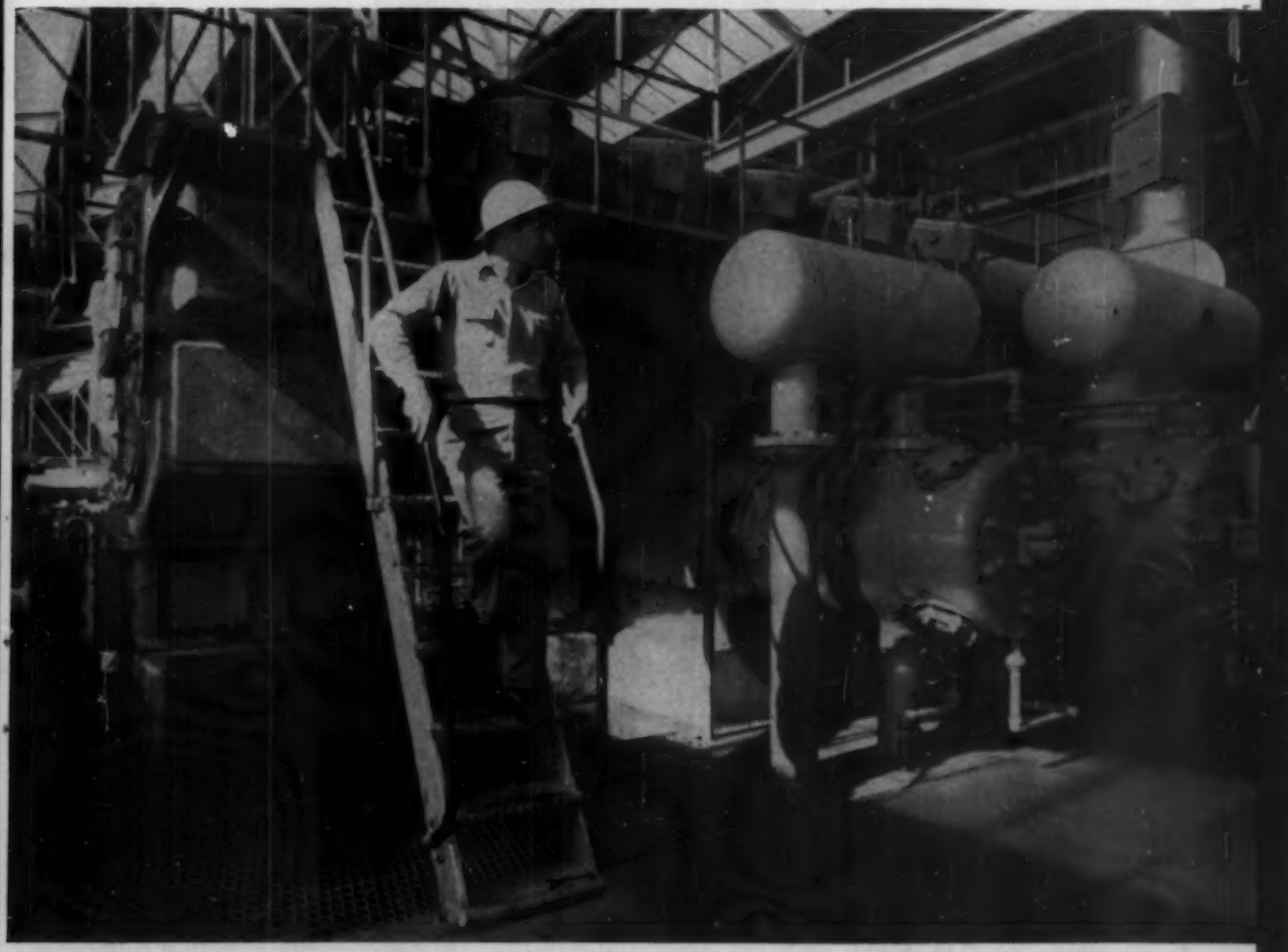
compressors to 5000 psi

These photos show both sides of one of the two Cooper-Bessemer 2500 hp GMW gas engine compressors at the Fortier Plant of American Cyanamid Company, Avondale, Louisiana. In the production of anhydrous ammonia, these 4-stage units compress 6000 cfm of synthesis gas from 60 psi to a discharge of 5000 psi. The left-hand view shows the high pressure cylinders; that on the right shows the low pressure side. The four stages of compression from 60 psi are (1) to 225 psi, (2) to 670 psi, (3) to 1500 psi, (4) to 5000 psi.

The two units have been operating since 1954, 24 hours a day, 340 days a year.

The anhydrous ammonia produced at the Fortier Plant is used by American Cyanamid in the manufacture of Acrylonitrile and is sold to fertilizer plants and other chemical companies.

Find out how Cooper-Bessemer can help *you* plan compression and power facilities. Write for copy of bulletin, "Cooper-Bessemer Equipment for Chemical Plants."



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Fertilizer output

from page 134

In the Ammo-Phos Process, the wet process is used to produce phosphoric acid. Then ammonia is reached with the phosphoric acid to produce mono-ammonium phosphate (Ammo-Phos 11-48-0), or a mixture of mono-ammonium phosphate and ammonium sulfate. This produces other grades of Ammo-Phos, such as 16-20-0, 15-30-0, and 13-39-0. Potash may be added to make NPK grades such as Ammo-Phos 12-24-12, 6-24-24, and 13-13-13.

Phosphate rock for the operation arrives from the Tampa, Florida, area via the Gulf of Mexico; ammonia from the company's Lake Charles, La. plant, and potash from New Mexico. The plant location at the transportation hub, the Houston ship channel, makes possible economical distribution to midwest markets via Mississippi, Missouri, and Ohio River barges.

Calspray complex

California Spray-Chemical has also thrown its hat into the ring, putting a $5 million complex on stream at Kennewick, Washington, on the Columbia River. This further expands its position as one of the largest producers of nitrogen fertilizers in the West. The new facility will make liquid and dry Ortho fertilizers, including a high analysis plant food. Its four units: nitric acid, ammonium nitrate, liquid, and complex plant foods, will use anhydrous ammonia piped in from nearby Phillips Pacific Chemical.

Technically, the interesting innovation is in the 300 ton a day complex plant food unit, where the Chemical & Industrial Corp. Process is combined with Societe Potasse et Engrais Chimiques (PEC) Process. This, according to C&I, gives a better pellet, reduces recycle rate and eliminates much of the equipment necessary in conventional plants. The process uses nitric rather than sulfuric acid to acidulate phosphate rock. This gives an immediate combination of nitrogen and phosphorus. Ammonia and sulfuric or phosphoric acid are added in amounts required to complete the reaction. This process makes all the P_2O_5 available as plant food. The slurry, under pressure, is then sprayed into the spherodizer where it is simultaneously pelletized and dried. This is done by spraying the feed slurry onto curtains of falling product particles showered through hot drying gases in a rotating drum. The pellets

continued on page 141

LUMMUS

ENGINEERS AND CONSTRUCTORS FOR INDUSTRY

INDIA'S FIRST SYNTHETIC RUBBER PLANT SET FOR SYNTHETICS AND CHEMICALS, LTD.

Lummus to Design, Engineer and Construct 30,000 Ton Per Year Plant Near Bareilly, India

The Lummus Company has been awarded the contract to design, engineer and construct a 30,000 ton per year synthetic rubber plant near Bareilly, Uttar Pradesh, India for Synthetics and Chemicals, Ltd. This firm was recently formed by The Firestone Tire & Rubber Company in association with the banking and industrial firm of Kilachand Devchand and Company Private, Ltd. of Bombay.

The 30 million dollar project will include plants for the production of butadiene and styrene, the principal raw materials, as well as a copolymer plant to manufacture the final product, synthetic rubber. In addition, Lummus will construct all the plant utilities and offsites. Although Lummus will design the plant for a capacity of 30,000 tons or more per year, the initial annual production will be 20,000 tons. Technical divisions of The Firestone Tire & Rubber Company are furnishing the basic engineering and know-how for the butadiene, styrene and copolymer units.

The plant site has been established in the heart of the sugar cane and alcohol producing area, and the alcohol obtained from the sugar cane will be the source of the butadiene, the principal ingredient of synthetic rubber.

Indian technicians and operating personnel will be trained to run the plant, whose final products will meet standard world-wide industry specifications.

Financing of the project will be assisted by a 27,100,000 Indian rupee (or $5,700,000) loan from the Export-Import Bank of Washington to Synthetics and Chemicals, Ltd. This constitutes the largest foreign currency loan in the bank's history. The remainder of the financing will come from private banks in the United States and the United Kingdom as well as from India.

The project is expected to save India approximately 10 million dollars in foreign exchange annually.

Lummus has over 50 years' experience in the design and construction of more than 850 plants for the process industries throughout the world. Call Lummus on your next project.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, New York, Houston, Washington, D. C., Montreal, London, Paris, The Hague, Madrid; Engineering Development center: Newark, N. J.

For more information, turn to Data Service card, circle No. 146

A.I.Ch.E. RESEARCH COMMITTEE

Final Report from the University of Michigan

Tray Efficiencies in Distillation Columns

PUBLISHED JUNE 1960

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PUBLISHED SEPTEMBER 1959

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Final Report from the University of Delaware

PUBLISHED DECEMBER 1958

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prediction of fractionation efficiency

by the Distillation Subcommittee of the Research Committee

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( ) Final Report from North Carolina State College
( ) Final Report from the University of Delaware
( ) Bubble Tray Design Manual

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Fertilizer output

from page 138

increase in size coat by coat, onion fashion. Three types of pellets are turned out by this unit: 14-14-14, 20-10-0, and 20-20-0.

Other plant units

The ammonium nitrate unit has a capacity of 200 tons a day of product in solution, or 150 tons of dry prill. C&I's process which uses a tower less than one-third as high as conventional prilling towers, gives finished prills containing 33.5% nitrogen.

A styrene monomer plant with a design capacity of 70 million pounds annually, will be constructed by Badger under a contract awarded by Sinclair-Koppers Chemical. Site is Houston (Pasadena), Texas. The ethylbenzene content of a mixed xylene stream produced in Sinclair's Houston aromatics extraction unit will be used to recover the hydrocarbon. Entire output of the plant goes to the Koppers Co. Process used is the "styrene from gasoline" process developed jointly by Cosden and Badger.

License for the use of Cosden's technique for manufacturing polyisobutylene goes to Naphtachimie, Paris-based firm. When these facilities are completed, the French firm will be one of the only producing sources in Europe for this material. The license is exclusive for the European common market.

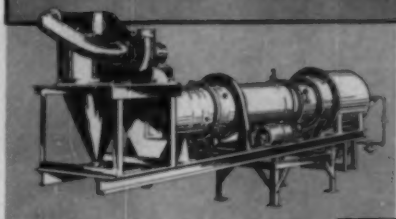
Construction of facilities to manufacture sodium hexametaphosphate gets underway at Hooker's Jeffersonville, Ind., Phosphorus Division headquarters. Aso underway at Jeffersonville are new tetrapotassium pyrophosphate facilities.

Semi-commercial production will be centralized at Hooker Chemical, with plans underway for a $1½ million building at Niagara Falls, N.Y. The semi-commercial equipment in the building is designed for maximum flexibility so that a succession of products can be processed in the same equipment, and several processes can be operated at one time.

Start-up of an anhydrous aluminum chloride plant at Sarnia, Ontario, Canada, by Clinton Chemical makes St. Clair Chemical, Clinton subsidiary, one of the only Canadian plants producing this chemical. The Sarnia facility has a capacity of 4 million pounds a year.

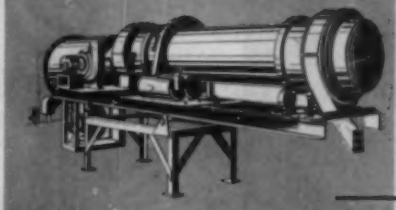
Pilot Plant or Laboratory Equipment . . .

for DRYING



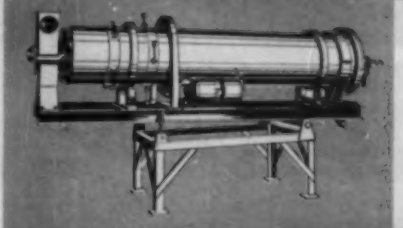
SINGLE-SHELL DRYER

Single-shell, direct gas fired rotary dryer. Arranged for either parallel or counter-flow operation. Mounted on structural steel base. Has removable "knockers." Bulletin AH-471.



DOUBLE-SHELL DRYER

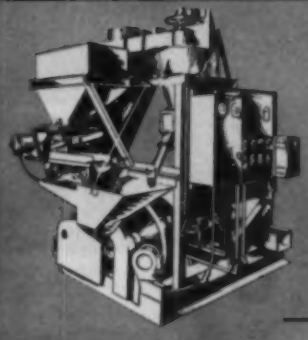
Double-shell, indirect-heat, gas-fired dryer for drying without contamination. Volatiles removed with only limited dilution. Shell rotation speed and shell slope easily changed. Bulletin AH-472.



STEAM TUBE DRYER

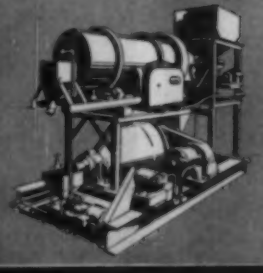
Steam-tube indirect heat dryer. Can be connected to any available steam supply or furnished with a 3-HP steam generator. Available in stainless steel or other corrosion-resistant materials. Easily moved from place to place. Bulletin AH-473.

for GRINDING AND CLASSIFYING



DRY GRINDING UNIT

Make power connections only and the Hardinge Dry Grinding Unit is ready to perform. Self-contained and portable, 7' 8" high. Complete with Constant-Weight Feeder, Conical Mill, "Gyrotor" Classifier, dust collector, product collector and "Electric Ear" grinding control. Bulletin AH-448.



WET GRINDING UNIT

Power and water connections only are needed to put the Hardinge wet grinding unit into operation. Self-contained and portable, 6½' high. Includes Conical Mill, Counter-Current Classifier, launders, feeder, pump and "Electric Ear" grinding control. Bulletin AH-448.

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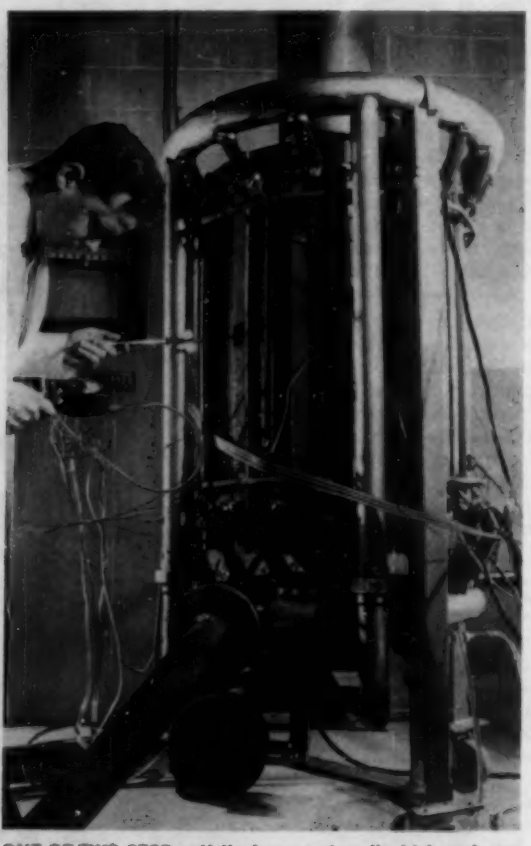
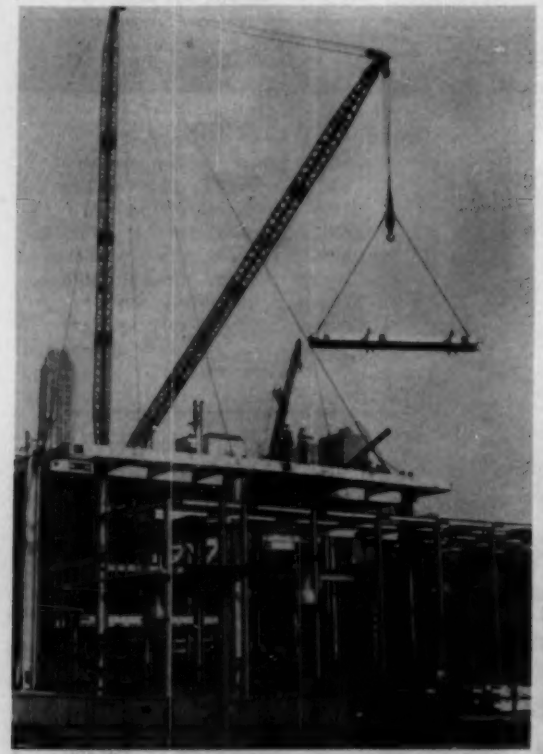
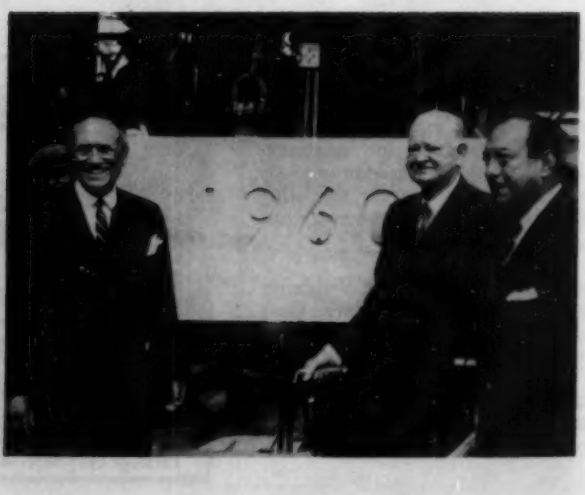
A NEW VINYL PLASTIC, said to withstand temperatures 60 degrees higher than conventional vinyls, is demonstrated by B. F. Goodrich Chemical. The weighted strips in the 180-degree water test above are (l. to r.) the new vinyl, polyamide, high-density polyethylene, and conventional vinyl. The new material, a polyvinyl dichloride, shows no sag.



ONE OF TWO 2500-watt "sub-generators," which make up the largest thermoelectric power plant ever constructed, under test at Westinghouse's new products laboratories. Developed for the Bureau of Ships, U.S. Navy, the generator delivers five kilowatts of electric power by the direct conversion of heat into electricity. It is 50 times more powerful than any previously described thermoelectric power plant.



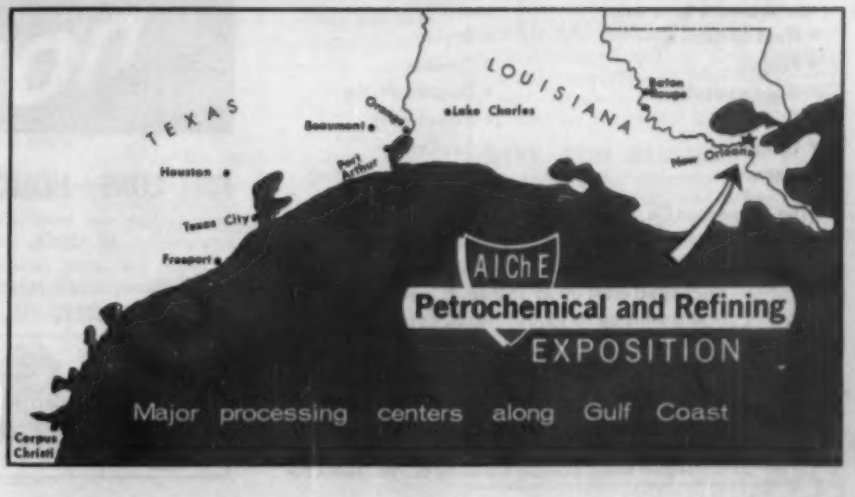
(ABOVE) STEEL GOES up as the United Engineering Building moves rapidly toward completion. In a recent ceremony, the cornerstone (right) was laid by former President Herbert Hoover and New York's Mayor Robert Wagner as Andrew Fletcher, UET president, (left) presided.



International Congress at Mexico City

A FEATURE OF THE OPENING ceremonies of the International Congress of Chemical Engineering held in Mexico City in June were the welcoming addresses of the presidents of the two sponsoring societies. (Right) Ricardo Millares, president of Instituto Mexicano de Ingenieros Quimicos, opens the meeting with his welcoming address. (Below) Jerry McAfee, A.I.Ch.E. president, responds to the welcome. McAfee presented the I.M.I.Q. with a complete bound set of CEP and the former A.I.Ch.E. Transactions as an expression of appreciation.

THE GULF COAST is the center of the petrochemical industry of the U.S. and additionally includes one-third of the petroleum refining capacity of the U.S. Plants are clustered around the major processing centers of Houston, Texas City, Beaumont-Port Arthur, Lake Charles, Baton Rouge and New Orleans. This latter city is also the site of the forthcoming Petrochemical and Refining Exposition sponsored by A.I.Ch.E. and to be held in conjunction with its national meeting, February 26-March 1, 1961.



local sections

New product development, equipment advances, at New Jersey Joint Meeting

COMMERCIAL CHEMICAL development, and advances in equipment design and construction, were co-featured at the **North Jersey** and **New Jersey Sections** All-Day Symposium in May. The eleventh annual joint meeting of the two groups covered the development of a new product from conception through commercial fruition. Included in four papers presented at this session were: *An Introduction to Commercial Chemical Development*, L. E. Johnson, International Nickel; *Market Research Techniques*, D. S. Alcorn, Union Carbide; *Publicity and Advertising*, D. R. Cannon, McGraw-Hill; and *Organization of Commercial Chemical Development*, A. J. Green, Pfizer.

Equipment Symposium

Mixing Processes in Multistage Contactors, J. Y. Oldshue discussed the different types of chemical engineering processes that can be carried out in a continuous multistage contactor. Four of these stage efficiencies were defined; each of these processes has its own requirement for mixing and scale-up characteristics. Accurate prediction of column performance can be made by determining whether mass transfer or reaction effects are controlling.

In The Fabrication of Tantalum, Titanium, and Zirconium Equipment, B. S. Payne pointed out that welding the special metals is not particularly difficult after correct procedures are fully understood by the fabricator. A higher standard of fabrication quality is required not only due to the unusual problems involved but also the expense of the material in use.

The Design of Optimum Cycle Thermal Process Plants, Donald Q. Kern said, has not included an assured period of uninterrupted production as a design requirement. This is due to certain conceptual inadequacies in distillation, evaporation, crystallization, and heat transfer as unit operations.

Guest at the dinner winding up the meeting was F. Buckminster Fuller, designer-builder-lecturer, who spoke on Generalized Structures, Visible and Invisible.

Tyler Award

Maurice E. Brooks and Valentine Mekler received the **New York Section's** Tyler Award for 1959. The Award was presented to Brooks for his co-authorship of "When is Delayed Coking Worthwhile," an article which appeared in *Petroleum Refiner*, June 1959. Mekler is director of technical services, and Brooks is vice president and director of engineering, The Lummus Co. Judges for this year's contest were F. A. Zenz, Associated Nucleonics, winner last year; D. F. Othmer, Brooklyn Polytech; and R. E. Treybal, N. Y. U. The Award, in honor of Stephen L. Tyler, past secretary of A.I.Ch.E., celebrates

continued on next page

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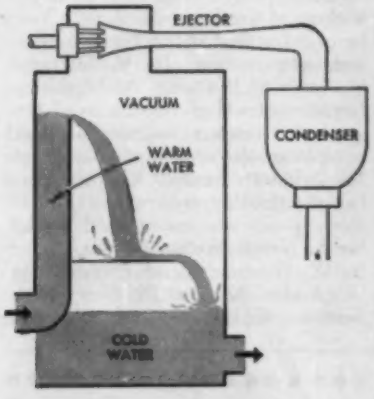

Simplified schematic diagram of steam jet cooler with surface condenser.

The simplest, most economical way to cool water is to use an Ingersoll-Rand Water-Vapor Refrigeration Unit with a steam-jet cooler. In this system, water is the only refrigerating medium. It *cools itself* by direct evaporation in a high vacuum created by steam-jet ejectors. The small portion of water that is evaporated gives enough cooling effect to chill the remainder.

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For more information, circle No. 79

Local sections

continued

Brooks (l.) and Mekler (r.), winners of the 1959 Tyler Award, with J. V. N. Dorr, who made the presentation.

that member who in the opinion of the judges, has published the best article, book or other paper in the preceding year. Ceremony took place at the May meeting.

Student night at Pittsburgh

Outstanding chemical engineering students from local colleges were honored at the **Pittsburgh Section** meeting in March. The three juniors who earned the highest grades during the year: Edward H. Blum, Carnegie Tech, Reid Crookston, U. of Pittsburgh, and James E. Mitchell, West Virginia U., were presented with scholarship awards by Jerry McAfee, president of A.I.Ch.E. Professional Promise Awards went to six chemical engineering seniors: Robert T. Wotring and Lester C. Long, Jr., West Virginia U.; Charles M. Bryson and George Weissert, U. of Pittsburgh; Richard B. Aust and John Friedly, Jr., Carnegie Tech. They were selected for this honor not only on the basis of outstanding academic work, but also for leadership and administrative abilities required of the modern engineer. This is an innovation over the usual award, made strictly on the basis of judgment of a technical report. The concept of professional promise, an attempt to evaluate it, and possible success as a professional are included.

Jersey student symposium

Student members from metropolitan chapters of A.I.Ch.E. and ASME met at Newark College of Engineering for an all day symposium in April. Representatives of nine colleges and universities held two separate meet-

continued on page 148

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Approximate chemical analysis

Loss @ 105°C.	0.60%
Further Loss on Ignition	3.25%
Silica (SiO_2)	73.77%
Alumina (Al_2O_3)	12.66%
Ferric Oxide (Fe_2O_3)	4.16%
Magnesia (MgO)	3.80%
Calcium Oxide (CaO)	0.34%
Ferrous Oxide (FeO)	0.08%
Sodium Oxide (Na_2O)	0.84%
Potassium Oxide (K_2O)	0.09%
Titanium Dioxide (TiO_2)	0.79%
Arsenic Oxide (As_2O_3)	0.00056%
Mercuric Oxide (HgO)	Less than 0.00005%*
Lead Dioxide (PbO_2)	Less than 0.00007%*
	Less as lead dioxide
Phosphorus Pentoxide (P_2O_5)	0.22%
Sulfate (SO_4)	0.17%
pH around 5	

*None found.

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from page 145

ings and technical paper contest. They were guests of the college, as part of its 75th anniversary celebration.

F. J. Van Antwerpen, executive secretary of A.I.Ch.E., Sidney Kirkpatrick, former vice president of McGraw-Hill Publishing Co., and Robert E. Treybal, professor of chemical engineering, N.Y.U., spoke to one group on *Chemical Engineering, Past, Present and Future.* Both groups were addressed by Raymond Fremed, associate editor of *Chemical Engineering,* on *Professionalism vs. Unionism.*

El Dorado Section

Waste disposal is now of such importance that it should be included in our plant process designs, Gustaf Panula told the **El Dorado Section** *(Henry A. McCandless)* in March. The Public Health Service grants about 1¢ per person per year for research on pollution. Panula reported on a project just completed on Pollution abatement studies conducted by the Louisiana Polytechnic Institute's Department of Engineering Research. The studies were made for the Public Health Service, U.S. Department of Health, Education and Welfare.

Present water consumption rate per capita in the U. S. is about 150 GPD. A city the size of Detroit will consume 330 MGPD of water on a June day. A billion tons a year of silt is carried by waterways and about ⅛ of this is carried by the Mississippi River. But, he added, building of dams on the head waters have substantially reduced silt loads.

De-oiling solvent

The wet solvent process for de-oiling wax, a by-product of lube oil manufacture, was discussed by Jack Warnecke, Union Oil of California, at the **Northern California Section** *(William B. Hauserman)* in March. The solvent used, methyl-isobutylketone, has the advantage, compared with other de-oiling solvents, that the elimination of water from it is much simpler. Its effectiveness as a de-oiling solvent is relatively unaffected by its water content. Estimated cost saving on the process, currently in use at Union Oil's Oleum refinery, is over 50 percent. Increase in production is 70 percent beyond that which would be realizable by use of other common solvents for this purpose.

TV in Western New York

A film on careers in chemical engineering was shown in March by the **Western New York Section** *(Reed E. Garver).* One of a series of Wednesday evening programs on a local TV station, the program was part of the Section's career guidance project.

Also meeting

Boston Section *(Ralph Wentworth)* members got a glimpse of Eskimo life from Robert F. Jasse, March speaker, who spent nearly a year in the Northland . . . Robert L. Sproull, Cornell U., spoke to the **Rochester and Syracuse Sections'** joint meeting in April on *Application of Solid State Physics to Engineering.* . . . A talk on recent developments in the archaeology of the lower Mississippi Valley was featured at the **Western Massachusetts Section** *(D. M. Sullivan)* in April. S. Williams, Anthropology Department, Harvard U., was the speaker. Occasion was annual joint banquet of the Section and the U. of Massachusetts Student Chapter . . . Current thinking on irreversible thermodynamics was summarized at the **South Jersey Section** in March by R. W. Houston, U. of Pennsylvania . . . Ladies' Night at the **New Jersey Section** *(E. M. Powers)* in April

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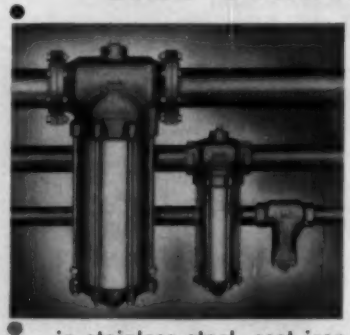

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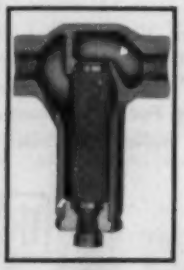

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heard Mason Gross, president Rutgers U. . . . Statistics should be used as a tool to generate ideas for highlighting experimental results, J. S. Hunter told the **Maryland Section** (*J. W. Holtz*) in April. Editor of the monthly, *Technometrics*, and U. of Wisconsin staff member, Hunter described how statistical analysis is used in the design of experimental programs in production, development and research . . . Statistical thinking for the engineer was also in the news at **Northern West Virginia Section** (*Joseph E. Fraker, Jr.*). April meeting, held jointly with ASSQC . . .

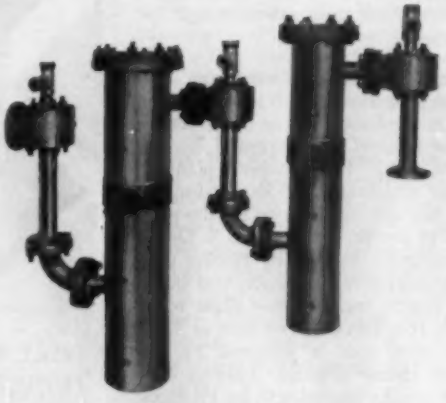
Construction of a plant to produce ortho-xylene at Cities Service Refining, Lake Charles, La. gets underway shortly. Basic feed stocks for the 120 million pound a year unit will come from present company units at the location.

A paper on *Improving Black Liquor Oxidation in Packed Towers* was presented to the **Southwest Washington Section** (*James C. Tooley*) by William West, Crown Zellerbach, in March . . .

A tour of the Martin facilities, where the Titan Intercontinental ballistic missile is made, took up the April meeting of the **Rocky Mountain Section** (*A. L. Benham*) . . . The **South Texas Section** (*G. H. Cummings*) heard Enrique Rangel on the Mexico City joint meeting of A.I.Ch.E. and I.M.I.Q. . . . J. W. Joyce, NSF, gave an account of IGY investigations through 1958, at the **Charleston Section** (*G. O. Walker*) in March . . . A talk on the separation of silica and hafnium from zirconium in zircon sand was **Southwest Louisiana Section** (*Robert L. Goodkind*) topic in April. F. J. Seeba, Columbia-Southern Chemical, was the speaker . . . The **Chemical Engineers Club of Washington** annual field trip was made to the U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va. in May . . . J. J. McKetta, U. of Texas, addressed the **East Texas Section** (*E. N. Livingston*) in April on "Are You a Professional Engineer?" . . . Some of the techniques employed in operations research were discussed by George E. Kimball, Arthur D. Little, at the **Sabine Area Section** (*Norman Wacks*) in April.

Synthetic rubber and latices will be produced at Firestone's new installation at Port-Jerome, France. The 10,000 long ton annual capacity unit is due for completion in 1961.

a jet for every job



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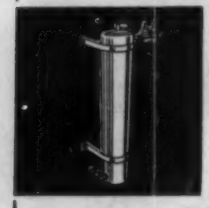

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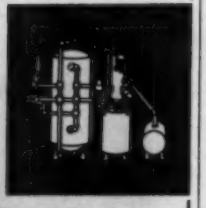

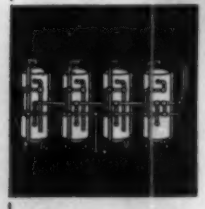

MULTI-COLUMN
Any combination of anion and cation exchangers in sizes to meet any need.
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Whatever the purity of water you need or the quantity you desire, Elgin can supply the correct type and size ion exchange equipment to deliver it. No requirement is too small—none too large for Elgin to handle efficiently. Whether it is a standard deionizer or one specially designed for the job, you are assured of expertly engineered equipment and trustworthy service for which Elgin has been known more than a half century.

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180 N. Grove Ave., Elgin, Illinois
Representatives in Principal Cities
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For more information, circle No. 46

industrial news

A new producer of special metals comes into being, Reactive Metals. National Distillers has acquired a 60 percent interest in the common stock of Mallory-Sharon Metals, and will integrate with it the operations of its subsidiary, Johnston & Funk Metallurgical. The combined operation will produce zirconium, and titanium mill products and columbiun, hafnium, molybdenum, tantalum, tungsten and vanadium. Offices of the company are at Bridgeport, Conn.

The manufacture of synthetic rubber goes ahead in Japan, with a $30 million plant on stream at Yokkaichi. Owned by Japan Synthetic Rubber Co. Ltd., the plant was designed for an annual output of 40,000 metric tons of SBR crumb rubber and 5000 of synthetic latex. Total Japanese rubber consumption of 190,000 tons in 1959 is expected to reach 220,000 this year, and 300,000 by 1965.

A plant to be built near Beaumont, Texas, By Goodyear, will make Natsyn (isoprene) and Budene (butadiene). Both synthetics were formerly made in pilot plant quantities. Budene is an extender, Natsyn an extender and replacement.

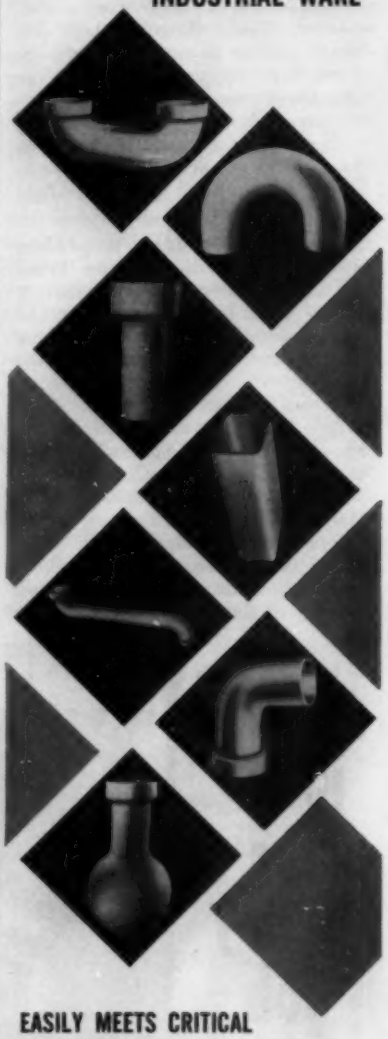
Hooker Chemical's expansion in phenol goes ahead, with a plant to be built in Kentucky, where construction will be finished, it is expected, by the end of 1961. For Hooker's planned unit in Argentina, the Export-Import Bank has approved a loan for the purchase of equipment in the U.S. Duranor, company formed by Hooker and the Argentine firm, Atanor, will build a 25 metric ton per day plant on a site in Rio Tercero, Province of Cordoba. The spot is adjacent to the Atanor chemical plant. Largest customer for the phenol will be Plasticos Atanor, Atanor subsidiary.

A hydrodealkylation unit to be erected at Ashland Oil and Refining, Catlettsburg, Ky. will use the UOP and Ashland jointly developed Hydeal process. Design capacity is 75 million pounds a year of naphthalene, and 15 million gallons a year of benzene.

Engineering and construction of a butadiene extraction plant in Grangemouth, Scotland, will be done by Fluor for British Hydrocarbon Chemicals, Ltd. One of three new facilities for BHC, completion is slated for 1961.

VITREOSIL®

PURE FUSED QUARTZ INDUSTRIAL WARE



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Many standard shapes and sizes . . . and we fabricate for special needs. See our ad in **Chemical Engineering Catalog.**

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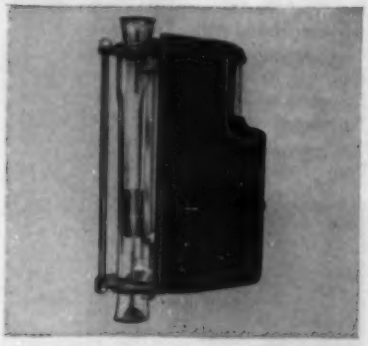

or one with a halofluorocarbon metering tube like this . . .

In fact, we can make a meter to just about any material specifications you might want.

This eight-page bulletin . . .

describes more than a dozen of the many materials available and gives meter construction details. Ask for Bulletin 150, and it's yours.

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For more information, circle No. 14

industrial news

A new chemical center planned by Archer-Daniels-Midland will make nitrogen plasticizers, esters, olefins, and other intermediates. To be built on a 200 acre site near Peoria, Ill. the operation is scheduled to begin in early 1962.

An expanded sulfuric acid plant at Pittsburgh Chemical's Neville Island installation will boost company capacity by 70 percent.

Construction of an ethyl chloride-ethylene dichloride plant at Corunna, Ontario, is underway for Ethyl Corp. Work, by Badger, is slated for completion in mid-September.

A high pressure sulfur removal plant to be constructed in Pancevo, Yugoslavia, by a West German firm, Pintsch Bamag A. G., will use the Alkazid process. Pintsch Bamag will provide training for Yugoslav operating personnel in their West European alkazid plants.

A join research and development program for liquid rocket propellants will be inaugurated by Du Pont and North American Aviation. Under an agreement, candidate propellants will be manufactured in experimental quantities by Du Pont, while the Rocketdyne Division of North American will test them and develop performance data.

A 400 ton a day oxygen generating plant now under construction at Mingo junction, Ohio, will distribute oxygen to Wheeling Steel, and liquid oxygen and argon for industrial use. A joint venture of Hydrocarbon Research and Wheeling Steel, Mingo Oxygen Company will use HRI's air separation process. The $6 million plant is expected to be in operation by late 1960.

A new Franco-American company will build power and research reactors in France and the French Union. The joint venture of Atomics International, (North American Aviation), Societe Alsacienne de Constructions Mecaniques and Chantiers de l'atlantique, is most interested in sodium graphite and organic cooled power types and solution type research reactors. The new company called Dynatom has a proposal under consideration to build a 165 electrical megawatt organic moderated reactor plant near Ardennes, France, under the Euratom program.

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people
in management
and technology

Dorr honored by Brooklyn Polytech

John Van Nostrand Dorr, a past president of A.I.Ch.E., has received an honorary degree from the Polytechnic Institute of Brooklyn. The degree was conferred at the annual commencement exercises in June.

Dorr is honorary chairman of the Board of Dorr-Oliver, Inc., a company he founded, and one of the founding partners in the recently launched New York City firm, Dorr Consultants.

In the field since 1894, when he received a B.Sc. from Rutgers U., Dorr did lab research work under Thomas A. Edison. He is the inventor of such devices in the chemical processing and metallurgical fields as The Dorr Classifier, The Dorr Thickener and The Dorr Agitator.

He is author of *The Cyanidation and Concentration of Gold and Silver Ores,* and also of many technical papers. Dorr, one of only seven men to receive the A.I.Ch.E. Founder's Award, was president of the Institute from 1932-33. Included in his many honors are the John Scott Medal of the Franklin Institute, the James Douglas Medal of AIME, the Chemistry Industry Medal, and The Perkin Medal.

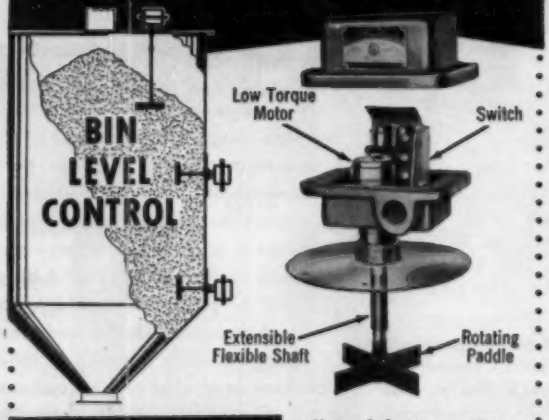
Ernst Weber (r) president of Brooklyn Polytech, who made the presentation, Dorr, and Dean Schaffner.

Lansing T. Dupree, assistant publisher of CEP, has left to join the Petroleum Engineer Publishing Co. On the A.I.Ch.E. staff for fourteen years, he was associated with CEP as sales manager when it was founded in 1947. In his new post, Dupree will represent both The Petroleum Engineer and the American Gas Journal, working out of the New York office.

James R. Dudley, vice president of research and development, The Richardson Co., has taken over the post of president, Commercial Chemical Development Association. On July 1 he moved up from president-elect of the organization. A graduate of Carleton College, Dudley has a Ph.D. from the University of Iowa. He holds memberships in ACS, AIC, AAAS, and CMRA.

Herschel H. Cudd, vice president, research and development, American

ROTO-BIN-DICATOR



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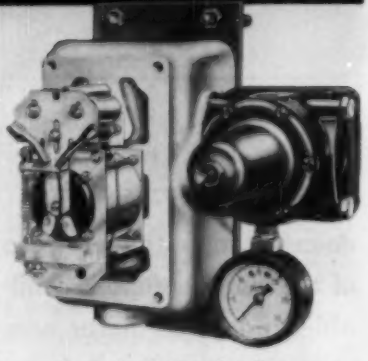
Available with or without a pneumatic valve positioner

Developed for use in electrical control loops where final control element is pneumatically operated. Explosion proof . . . ideal for use in hazardous conditions. Built in volume relay permits direct operation of actuator from transducer. No extra relays or boosters needed.



Input signals from 1 to 5 ma . . . output from 3 to 15 psi through 6 to 30 psi.

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For more information, turn to Data Service card, circle No. 16

Viscose, has been named president of AviSun. Before joining American Viscose in 1954, he had been director, Engineering Experiment Station, Georgia Institute of Technology. Cudd is on the Board of Directors, Industrial Research Institute, and a trustee, Textile Research Institute.

In a series of key personnel changes at B. F. Goodrich Chemical, **Antone Vittone, Jr.** was named manager of plants. He will be responsible for production facilities, product improvement and cost control. Succeeding him as director of development is **R. J. Wolf,** who will handle operations at the Avon Lake, Ohio, Development Center. **Benjamin M. G. Zwicker** was appointed director of planning, moving up from the post of new products planning.

C. C. Tsao has transferred to the Service Bureau Corp. (IBM) plant in San Jose, Calif. He will direct a program of advanced computations which will provide rocket fuel evaluations and distillation computations on a service bureau basis.

David L. Matthews has been appointed vice president, manufacturing, Goodrich-Gulf Chemicals. Prior to this, he was manager of manufacturing. Matthews had been with B. F. Goodrich since 1940, joining Goodrich-Gulf in 1955 as chief engineer. The appointment of **John Sabot** as coordinator of manufacturing operations is another staff change. Sabot joined Goodrich-Gulf in 1956 as project manager. At Port Neches, Texas, **Bodie C. Pryor** was appointed manager, polyethylene operations. The polyethylene facilities at the plant will be in operation later this year.

Roger N. Salesby, Jr. has been promoted to plant manager, Atlantic Research Pine Ridge facility at Gainesville, West Va.

S. M. Cavallaro has been appointed technical development manager, nitrogen processes, Valley Nitrogen Producers. He will handle expansion of facilities as well as new product development. **A. H. Sulliger** is plant manager.

continued on page 152

The LEHMANN CAN CODING MACHINE

marks them faster and better

The Lehmann Automatic Can and Package Coding Machine marks sixty cans per minute with a clean-cut permanent code mark. It uses a special opaque quick-drying ink that is not affected by the thin film of oil sometimes present on can lids.

The machine prints on tops or bottoms of cans or packages moving in any direction. It prints on cans of slightly different heights without adjustment. It stamps the code on containers in motion, without smearing.

The Lehmann Coding Machine fits on all types of can and package closing machines. It handles containers 1/32 to 1 gallon and prints up to 3 lines of 12 characters each. The machine is available in any voltage or air specifications.

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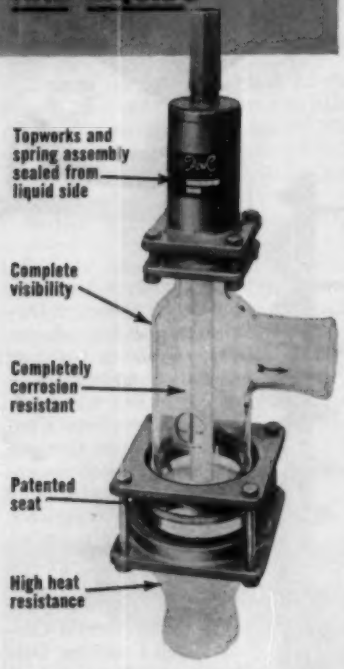
NEW

A "SEE-THROUGH" SAFETY-RELIEF VALVE THAT SEALS GASES AND LIQUIDS



A completely new concept in relief valve seat design plus *Pyrex & Teflon Construction for the added advantages of full visibility and corrosion resistance Seat pressure is completely independent of spring load. Valve reseats after venting without labor or material cost of rupture disc replacement. Ideally suited for both pressure and vacuum relief. Seals against liquids and gases. Use with liquid lines, with reactors and vessels of all types. Available in other materials of construction. Ask us for Bulletin RV-1.

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Permanent filter element offers maximum particle retention with very high flow rate. Porosity range, one to 100 microns. Use for sterilization, clarifying, polishing. Pyrex & Teflon construction for visibility and high temperature applications. Write for Bulletin FPT-2.

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For more information, circle No. 28

People

from page 151

New members of the Research and Development Department at Ethyl are **Oran A. Ritter, Jr.** and **Norman Guzick.** They are at the Baton Rouge, La. plant.

Albert Spiel has been promoted to section head at the General Foods Research Center, Tarrytown, N.Y. He has been a project leader since 1954, when he joined the company.

Robert E. Benge has joined Emery Industries, Engineering Dpartment. He will do designing work for the company's oleochemical plants.

George A. Omohundro has joined American Viscose as chemical process engineering supervisor, Central Engineering Department, Marcus Hook, Pa. Stepping into the newly created position of division tire yarn and staple development supervisor is **Hubert C. Gainer.** He will be located at the Front Royal, Va. plant.

Jane S. Popovich has joined the Research and Development Division, Du Pont Polychemicals Department. She recently received a B.S.Ch.E. from the University of Pittsburgh.

Recent promotions at Chemstrand are **Louis D. Scott,** to director, Acrilan manufacturing, and **Adin A. Nellis, Jr.,** manager, overseas technical services. **Paul H. Darmer** has been named superintendent of pilot operations and equipment development in the Acrilan development group. New member of the company is **Reginald H. Jonas,** personnel supervisor.

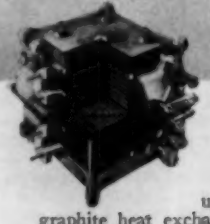
H. M. Killmar moves into the post of manager, manufacturing, at Carborundum's Refractories Division Perth Amboy plant at Latrobe, Pa., and the Globar plant at Niagara Falls, N.Y.

New member of the Board of Directors of National Starch and Chemical is **Sidney Thune.** Thune, associated with the company since 1932, is vice president, adhesive and resin sales. Starting in adhesives technical service, he has served in various capacities, including manager, New England, West Coast, and Midwestern Divisions. He has been a vice president of the firm since 1952.

New assignment for **Sidney M. Brunson** is project manager, C.S.R.C.-Dow

"STANDS UP *in the tough applications*"
. . . says still another user

'Delanium' Graphite BLOCK TYPE HEAT EXCHANGERS



PERFORMANCE REPORT 223

OPERATION: Condensing phosphorus oxychloride plus HCL at 280° F.

UNIT: Model 50/50 'Delanium' Graphite Heat Exchanger.

PERFORMANCE: Preliminary testing by the customer proved 'Delanium' to be the best graphite available for this service. Unit was installed in 1957. Customer reports complete satisfaction.

USER: New Jersey fine chemicals manufacturer.

The denser grade of graphite in 'Delanium' exchangers provides greater resistance to corrosion and mechanical abuse. Block-type design can handle operating pressures up to 200 psig against 40 to 50 psig for most other types of graphite heat exchangers. Occupies ⅓ the space of other units of comparable heat transfer surface. No internal gaskets between process and service streams; no floating heads, no packing. Sixteen models, 4 to 500 sq. ft. Temperatures to 360°F. and higher. Heaters, coolers, evaporators, condensers . . . for pharmaceuticals, agricultural chemicals, acids, organics and chlorinated solvents.

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Pty. He will supervise engineering and construction of the new ethylene dichloride plant at Melbourne, Australia, and also start-up operations. Since 1957, Brunson had been assistant production superintendent, Vinyl-Vinylidene Chloride Department, Texas Division in Freeport.

R. H. Waixel has joined the Technical Division, Humble Oil & Refining, Baytown, Texas.

Robert H. Aude has been appointed president, Heyden Chemical Division, Heyden Newport. He joined the company in 1953, and has been for the past two years vice president and general manager of the division.

James W. Call takes over the post of plant manager, Stauffer's new carbon bisulfide plant. The plant is now under construction in Wilmington, Delaware, and scheduled to be completed by the end of the year.

L. V. Clark has been appointed director of explosives research and development, American Cyanamid. He will direct work at New Castle, Pa. and at the Research Center, Bound Brook, N.J. Clark has been in the explosives field since 1927, and with Cyanamid since 1936.

William D. Kohlins has been advanced to vice president-general manager, Blaw-Knox Buflovak Equipment Division, Buffalo, N.Y. He joined the company in 1946 and has been Buflovak division manager since 1956.

C. W. Rackley has been promoted to assistant chief engineer, Tennessee Oil Refining (Tennessee Gas Transmission). He will work out of the Houston headquarters office. **A. R. Dudley, Jr.** replaces him as senior process engineer at the company's Chalmette, La. refinery.

Paul L. Breyfogle moves up to the post of superintendent, Dry Starch Section, A. E. Staley. Formerly assistant superintendent, Breyfogle has been with the company since 1947. He succeeds **Frank J. Rogier**, who retired after 28 years in the post.

George A. Coulman has been awarded a fellowship for work at Case Institute of Technology's Systems Research Center. The Fellowship, based on recommendations from the department in which the recipient has taken a degree, also went to eleven other graduate students.

Edwin H. Young has been elected

continued on page 154

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RECTIFICATION

- *Silicon*
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Complete Semiconductor Power Conversion Systems for any AC to DC application

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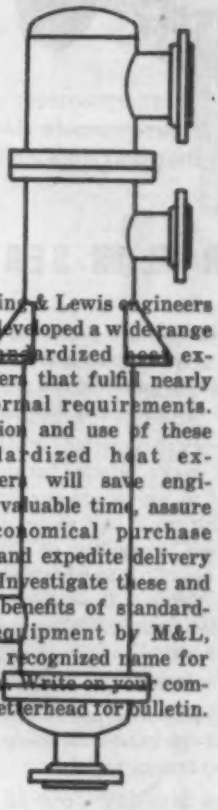
STANDARDIZED HEAT EXCHANGERS by M&L

A MARK OF QUALITY



Manning & Lewis engineers have developed a wide range of standardized heat exchangers that fulfill nearly all normal requirements. Selection and use of these standardized heat exchangers will save engineers valuable time, assure an economical purchase price and expedite delivery time. Investigate these and other benefits of standardized equipment by M&L, long a recognized name for quality. Write on your company letterhead for bulletin.

In addition, a new four-color bulletin describes and illustrates the complete M&L line. Specify Bulletin 820 in your request.

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SERV-RITE
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thermometer sockets
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FOR PLUS SERVICE

SERV-RITE drilled protecting wells are made in types, lengths, and of alloys to meet any temperature and pressure condition in vessels and flow lines.

Every well is carefully made to assure a plus service. Selected bar stock is machined to within accurate limits. Bore concentricity is held within 5% of wall thickness, depending on well length. They are tested to withstand pressures up to 3000 psi., depending on the wall thickness. Exterior surface has a mirror-like finish for minimum resistance to flow in lines.

Complete assemblies can also be furnished with suitable thermocouple, head, flange, fittings, etc.

Give SERV-RITE a trial on your next drilled well requirements. There is none better.

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For more information, Circle No. 24

People

from page 153

vice president, Michigan Society of Professional Engineers. Young, professor of chemical engineering at the U. of Michigan, has been on the board of directors of the state society for two years.

Daryl L. Lackey and **John A. Rauscher** are among the Monsanto men who will return to school in the fall on full salary. Both will be working toward master's degrees at schools of their choice.

Wayne C. Edmister left May 1 for four months of research work at the University of Amsterdam Van der Waals Laboratory, Holland. He will work with the famed Dutch physicist, A. M. J. F. Michels, discoverer of polyethylene plastic. Edmister received an International Research Award from ACS's petroleum fund. A member of Oklahoma U's chemical engineering faculty, he collaborated with Michels last year to design high pressure research equipment for a new chemical engineering lab at the university.

James A. Luker has been appointed chairman, Chemical Engineering Department, Syracuse U. Professor of chemical engineering, Luker was chairman of the department's executive committee since 1958. A graduate of Louisiana State, he received his M.S. from MIT and Ph.D. from Northwestern U.

Henry J. Noebels was a U.S. delegate to the first world wide convention, International Federation of Automatic Control, held in Moscow in June. Manager of applications engineering, Scientific and Process Instruments Division, Beckman Instruments, Noebels is also a director, Instrument Society of America, Analysis Instrumentation Division. At the meeting, he spoke on theoretical considerations in the use of chromatography for process control. A.I.Ch.E. is one of five organizations representing the U.S. in the Federation.

Raymond H. Marks has been appointed executive vice president, Cary Chemicals. Prior to joining the firm, Marks was with Monsanto, where for nine years he worked in various research, production and sales capacities.

Continued on next page

H&B
ESTABLISHED 1887

Jacketed Spring Loaded
PLUG VALVES

- 2-WAY OR STRAIGHT SPRING LOADED
- 3-WAY SPRING LOADED
- ANGLE SPRING LOADED
- AIR CYLINDER OPERATED SPRING LOADED—*all sizes and types*

LONG ON SERVICE . . . SHORT ON MAINTENANCE

H & B's new fully jacketed spring loaded plug valves feature an inverted tapered plug inserted and lapped into the housing from the bottom of the valve—then spring loaded. The spring wedges the plug to a perfectly tight seal, eliminating troublesome leaks. Easy to operate—no big handwheel . . . no freeze . . . no "breaking loose" necessary. Easy to clean. Made in two port or multi port design, with any special stop arrangement desired.

Bulletin J-57 sent on request

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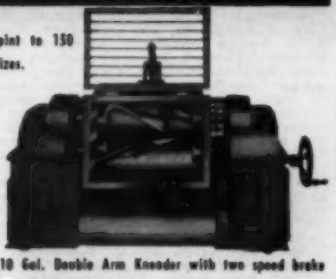
Leading mfrs. of
MIXING AND GRINDING EQUIPMENT
for over 90 years

• 1 pint to 150 gal. sizes.



#41L–10 Gal. Double Arm Kneader with two speed brake motor. Jacketed trough and motor operated lift optional.

• 4½ x 10, 6 x 14, 9 x 24, 12 x 30, 14 x 32, 16 x 40" sizes.

#32TC–14" x 32" High Speed Three Roller Mill. Hydraulic adjustment and pressure recording gauges optional.

#30C–50 Gal. Heavy Duty Change Can Mixer. Adjustable outer scraper, cover with charging port, and gates on cans optional.

• 8, 16, 20, 50 and 60 gal. sizes.

#130H–250 Gal. Change Tank Mixer with hydraulic raising and lowering and variable speed motor. Various type stirrers and high speed impellers optional.

• 80,150 and 250 gal. sizes.

#130EL–1 Gal. Double Planetary type Change Can Mixer with shearing action stirrers, and variable speed reversing type motor. Jacketed cans and portable trucks for cans optional.

• 1, 2, 3, 4, 6, 15, 25, 50, 65, 85, 110 and 150 gal. sizes.

Also Dry Crushing and Pulverizing Mills, Hopper Mills, High Speed Dissolvers or Dispersers, and Mixers of all types for dry, liquid, paste, or heavy paste materials.

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For more information, circle No. 121

People

continued

Marketing

W. A. Bours has been reelected director of the Vat Dye Institute. He is director of sales, Dyes & Chemicals Division, Du Pont.

James F. Zievers has been elected president, Foreign Sales Division, Industrial Filter & Pump. He is vice president and general sales manager of the company.

Henry J. Singer has joined GE's Chemical Materials Department, Pittsfield, Mass., as a sales trainee in the Marketing Section. He has completed training assignments at Cleveland, Ohio; Waterford and Schenectady, N.Y. under the company's CheMet program.

Robert L. Lambert has been appointed sales manager, American Cyanamid's Process Chemicals Department. He joined the company in 1933, and was formerly eastern regional manager of the department.

Henry W. Dahlberg, Jr. has been promoted at International Minerals & Chemical. His new post is administrative manager, Agricultural Chemicals Division-Sales.

S. David Ross has been named advertising manager, Fischer & Porter. Formerly an account executive at Harris D. McKinney, Philadelphia agency, Ross was before that with Honeywell's Industrial Division.

M. M. Reynolds takes over as director, sales and development, Cryogenic Engineering. Active in the low temperature field, Reynolds was first chairman of the Annual Cryogenic Engineering Conferences.

Richmond M. Stampley has become sales manager, West End Chemical (Stauffer). He was formerly manager, sodium sulphate and salt cake sales.

Necrology

Marlin G. Geiger, 63, executive vice president and director of W. R. Grace & Co. He was also president and chairman of the Board of International Metalloids, Grace Puerto Rican subsidiary, and a director and Board Chairman of Caribe Nitrogen, Puerto Rican firm under Grace management. A member of ACS and AAAS, Geiger held directorships in the Manufacturing Chemists' Association and in the National Plant Food Institute.

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future meetings

1960—MEETINGS—A.I.ChE.

• Buffalo, N. Y., Aug. 14-17, 1960. Statler Hilton Hotel. **4th National Heat Transfer Conference & Exhibit. Sponsored by A.I.Ch.E. & ASME. A.I.Ch.E.** sponsored panel discussion on **Discrepancies Between Design Procedure & Plant Operation.** Moderated by D. Q. Kern. Panelists: D. J. Bergman, Union Oil; C. H. Brooks, Sun Oil; C. H. Gilmour, Union Carbide Chem.; A. C. Mueller, Dupont, A.I.Ch.E. papers to S. W. Churchill, U. of Mich., Ann Arbor, Mich. ASME papers to J. P. Hartnett, U. of Minnesota, Minneapolis, Minn. Exhibit info to P. A. Jolcuvar, A.I.Ch.E., 25 West 45 St., N. Y. 36, N. Y.

• Cambridge, Mass, Sept. 7-9, 1960. M.I.T. **Joint Automatic Control Conference.** Sponsored by A.I.Ch.E. AIEE, IRE, ASME, ISA. For A.I.Ch.E. info refer to: W. H. Abraham, Eng. Exp. Sta., Dupont, Wilmington 98, Del.

• Tulsa, Okla., Sept. 25-28, 1960. Hotel Mayo. **A.I.Ch.E. National Meeting.** Gen. Chmn.: E. W. Kilgren, Pan Am. Petrol. Corp., Tulsa, Okla. Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co.., Bartlesville, Okla. See page 94.

• Longview, Wash., Oct. 7, 1960. **Pacific Northwest Section A.I.Ch.E. One-Day Regional Meeting** on general topics. Mtg. Chmn.: R. O. Bathiany, Weyerhauser Co., Longview.

• Washington, D.C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Gen Chmn.: J. L. Gillman, Jr., 1700 K St., N. W., Wash. 6, D.C. Tech. Prog. Chmn.: D. O. Myatt, Science Communication, Inc., 1079 Wisconsin Ave., N.W., Wash. 7, D.C. **Air Pollution**—A. J. Teller, U. of Florida, Gainesville, Fla. **Unsteady—State Instrumentation**—T. J. Williams, Monsanto Chem. Co., St. Louis, Mo. **Fluid Dynamics**—A. C. Acrivos, U. of California, Berkeley, Calif. **Information & Communications**—R. O'Dette, NSF, Wash., D.C. **Nuclear Reactor Operations**—R. L. Cummings, Atomics International, Canoga Park, Calif. **Nuclear Chemical Plant Safety**—C. E. Dryden, Ohio State U., Columbus, O. **Phase Transitions**—G. Bankoff, Northwestern U., Evanston, Ill. **Sales Overseas**—J. Costigan, The Sharples Corp., 501 Fifth Ave., New York 17, N.Y. **Chemical Engineering—A Vital Link in Broadening the Uses of Agriculture Crops**—J. E. Simpson, U.S.D.A. **Chemical Warfare—Dispersal of Materials in Aerosol Form**—L. E. Garono, Army Chem. Corps. **Role of the Chemical Engineer in Environmental Health Engineering**—W. L. Faith, Air Pollution Foundation, 2556 Mission St., San Marino, Calif. **Feeding, Clothing, and Protecting the Combat Soldier**—Leo Spano, Quartermaster R&Eng. Command, Natick, Mass. **Phenomena Affecting Materials in Extreme Environments**—J. Hearne, Air Force R&Eng. **Impact of Govt. Programs on Chemical Engineering Education**—W. K. Davis, Bechtel Corp. **Toxic Plant Construction**—L. E. Garono, Army Chem. Corps. **Potentialities of Fuel Cells as Power Sources**—P. Greer, Army OOR. **Saline Water Conversions**—J. J. Strobel, OSW, Dept. Int. **Chemical Engineering in the Mineral Industry**—H. Perry, Chf. Bit. Coal Res. Br., U.S. BuMines. **Rocket Propellants**—W. E. Sheehan, DDRE. **Economic Evaluation of New Processes**—J. H. Hirsch, Gulf R&D Co., P.O. Drawer 2038, Pittsburgh 30, Pa. **New Crystallization Techniques**— H. M. Schoen, American Cyanamid Co., 1937 W. Main St., Stamford, Conn. **Heat Transfer,** Papers requested—M. Altman, Gen. Elec. Co., 3198 Chestnut St., Philadelphia, Pa.

1960—Non-A.I.Ch.E.

• Seattle, Wash., Aug 8-11, 1960. Olympic Hotel. Western National Meeting **American Astronautical Society.** Prog. Chmn.: R. M. Bridgeforth, Aero-Space Div., Boeing, Seattle.

• Buenos Aires, Arg., Sept. 12-16, 1960. **Pan American Congress on Engineering Education:** Sept. 19-23, 1960. **7th Convention of Pan American Association of Engineering Societies.** For info: G. A. Hathaway, Chmn., Comm. on International Relations, EJC, 29 West 39 St., N. Y. 18, N. Y.

• Quebec City, Can. Nov. 6-9, 1960. **Canadian Chemical Engineering Conference** spons. by Ch.E. Div., CIC. Invitation extended to U.S. Chem.E.'s to present papers. Acceptance based on 700-word abstract to: W. J. M. Douglas, Ch.E. Dept., McGill Univ., Montreal, P.Q., Canada.

1961—MEETINGS—A.I.Ch.E.

• New Orleans, La., Feb. 26-March 1, 1961. Hotel Roosevelt, **A.I.Ch.E. National Meeting.** Gen. Chmn.: O. F. Wiedeman, Cyanamid, New Orleans, La. & H. E. O'Connell, Ethyl Corp., Baton Rouge, La. Tech. Prog. Chmn.: A. L. Regnier, Petroleum Chem., P.O. Box 6, New Orleans 6, La. **Brainstorming Technical Problems**—G. C. Szego, Space Technology Labs., P.O. Box 95001, Los Angeles 45, Calif. **Kinetics of Catalytic Reactions**—M. Boudart, Princeton U., Princeton, N.J. **Petrochemicals—Future of the Industry on the Gulf Coast**—J. A. Sherred, Monsanto Chem. Co., St. Louis 66, Mo. **Filtration**—F. M. Tiller, U. of Houston, Houston, Texas. **Settling**—A. G. Keller, La. State U., Baton Rouge, La. **Future Processing Technology in the Petroleum Industry**—A. F. Kaulakis, Process Res. Div., ESSO. **Education and Professionalism**—R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, O. **Mathematics in Chemical Engineering**—R. L. McIntire, Mathematical Eng. Assoc., 3108 Sweetbriar, Fort Worth 9, Tex. **Evaluation of R&D Projects**—L. A. Nicolai, 239 Parsonage Hill Rd., Short Hills, N.J. **Liquid—Liquid Extraction**—R. B. Beckman, Carnegie Tech., Pittsburgh 13, Pa. **New Petrochemical Processes in the Area**—B. G. Caldwell, Dow Chem. Co., Plaquemine, La. **Materials of Construction**—R. V. Jelinek, Syracuse U., Syracuse, N.Y. **Thermodynamics**—J. J. Martin, Ch.E. Dept., Univ. Calif., L.A. 24, Calif. **Use of Probability Mathematics in Economic Evaluation**—A. O. Bates, Atlas Powder Co., New Murphy Rd., Wilmington 99, Del. **International Chemical Picture**—L. Resen, CEP. **Selected Papers**—E. Mannings, Shell Oil Co., Norco, La.

Deadline for papers: Sept. 5, 1960.

• Cleveland, O., May 7-10, 1961. Hotel Sheraton, Cleveland. **Joint A.I.Ch.E. National Meeting with Ch.E.Div. C.I.C.** Gen Chmn.: H. Pforzheimer, Jr., Standard Oil Co. (Ohio), Cleveland, O. Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16.

continued on page 157

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O. **Petrochemicals as Starting Materials for Polymers**—L. F. Marek, A. D. Little, 30 Memorial Dr., Cambridge 42, Mass. **Fluid Mechanics**—W. H. Gauvin, McGill Univ., Montreal, Que. **Optimum Utilization of Pilot Plants**—J. T. Cumming, School Eng., Penn College, Cleveland 15, O. **Process Dynamics (Theoretical)**—R. M. Butler, Imperial Oil Co., Sarnia, Ont. **Synthesis Processes for Isoprene**—T. A. Burtis, Houdry Process Corp., 1528 Walnut St., Phila. 2, Pa. **Radioactive Materials for Process Control**—J. R. Bradford, College of Eng., Texas Tech. College, Lubbock, Tex. **Process Dynamics (Applied)**—L. M. Naphtali, Ch.E. Dept., Brooklyn Polytech., Brooklyn, N. Y. **New Synthetic Rubber Types**—P. M. Lindstedt, Goodyear Tire & Rubber Co., Ch.E.Div., Akron 16, O. **Coalescence**—R. Kintner, Illinois Inst. Tech., Chicago 16, Ill. **Management Criteria for Capital Investment**—C. P. Prutton, Food Machy. & Chem. Co., 161 E. 42d St., New York 17, N. Y. **Ch.E. in Metal Refining**—W. M. Campbell, Chem. & Met. Div., Atomic Energy of Can., Chalk River, Ont. **Heavy Metal Mfr.**—L. P. Scoville, Diamond Alkali, Union Commerce Bldg., Cleveland 14, O. **Applications of High Speed Photography**—A. I. Johnson, Univ. of Toronto, Toronto 5, Ont. **Bulk Fibrous Materials**—R. M. Christiansen, Stearns-Roger Mfg. Co., Denver, Colo. **Pulp and Paper**—J. L. McCarthy, Univ. Washington, Seattle 5, Wash. **New Research Techniques**—D. Hyman, Cyanamid, 1937 W. Main St., Stamford, Conn. **Mixing-Fundamentals**—J. Y. Oldshue, Mixing Equipment Co., P. O. Box 1370, Rochester, N.Y. **Mixing-Applications**—E. E. Ludwig, Dow Chemical, Freeport, Tex. **Cash Flow Methods in Economic Analysis**—D. D. MacLaren, Esso Research & Engg. P. O. Box 215, Linden, N.J. **General Papers**—D. J. Porter, Diamond Alkali, P. O. Box 348, Rsch. Center, Painsville, O. **Student Program**—H. B. Kendall, Case Inst., 10900 Euclid Ave., Cleveland, O. Deadline for papers: Dec. 7, 1960.

• Lake Placid, N. Y., Sept. 24-27, 1961. Lake Placid Club. **A.I.Ch.E. National Meeting.** Gen. Chmn.: B. I. MacDonald, Jr., G. E., Waterford, N. Y. Tech Prog. Chmn.: E. R. Smoley, 30 School Lane, Scarsdale, N. Y. **Process Management; Commercial Chemical Development; Sales Engineering; Kinetics; Materials Handling; Growth Process Industries; Organization of Companies; Chemical Engineering in the Photographic Industry; Control of Corporate Investment Costs; Techniques and Practices in Plant Maintenance; Pilot Plants.**

• New York, N. Y., Dec. 3-6, 1961. Hotel Commodore. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: L. J. Coulthurst, Foster Wheeler Corp., 666 Fifth Ave., New York 19, N. Y. Tech. Prog. Chmn.: A. V. Caselli, Shell Chem. Corp., 50 W. 50 St., N. Y. 20, N. Y. **Heat Transfer; Management; New Processes; Nuclear Engineering; Water Pollution; Process Dynamics; Pilot Plants; Fundamentals; Petroleum & Petrochemicals; Fluids; Fluidization; Sublimation; Adsorption; Student Program.**

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.

Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.

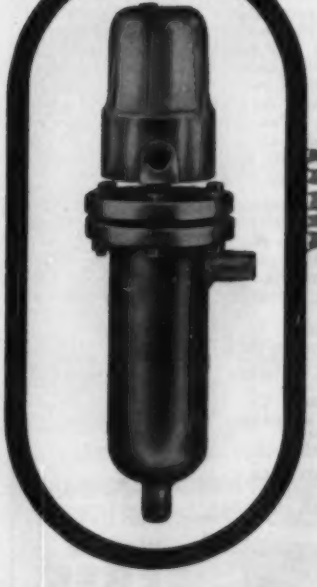
Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. of Mo., Columbia, Mo.

Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

Drying—R. E. Peck, Ill. Inst. of Tech., 330 So. Federal, Chicago, Ill.

Plan to Attend

The Petrochemical and Refining Exposition to be held in conjunction with the National A.I.Ch.E. Meeting in New Orleans, Feb. 26-Mar. 1, 1961. The theme will be the Chemical Engineer's role in design and development of petroleum and petrochemical facilities.



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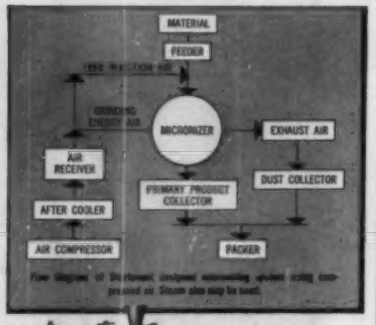

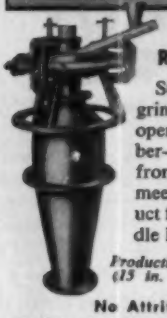

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industrial news

Plans for a pharmaceutical manufacturing plant in Karachi, Pakistan, are underway. Through its subsidiary, Lederle Laboratories, American Cyanamid will produce antibiotics, sulfas and nutritionals at the new facility. Already approved by the Pakistani government, the $½ million plant is expected to go on stream by the end of 1960. Operations will include packaging, tableting, encapsulating, as well as formulating drug products for the Pakistani market.

An expansion program underway at Naugatuck Chemical Division, U. S. Rubber, will raise the Painesville, Ohio, plant capacity for producing plastisol-grade vinyl resins by more than 30 percent. This brings it to 65 million pounds a year.

A $6 million technical center planned by Pennsalt Chemicals at King of Prussia Park, Philadelphia, Pa., will have as first part of the complex a 21,000 square foot laboratory devoted to product development and technical service.

Expansion program now underway at Michigan Chemicals takes in acquisition of Metropolitan Laboratories, injectable drug firm, as part of its ethical pharmaceut-chemical division. Also in the works are plans to double the capacity of the bromine plant which Michigan owns, along with Murphy, at El Dorado, Arkansas. Construction is already underway.

New facilities at Western Petrochemical's refinery include a TCP Wax Treater Process Unit. One of the first of its kind, the unit provides continuous bleaching of wax products instead of conventional batch bleaching. Also near completion at the Chanute, Kansas, refinery are a propane deasphalting unit and additional vacuum distillation units.

In a merger between Texas Butadiene & Chemical and Industrial Rayon, the latter firm will acquire Texas Butadiene for approximately 1,675,000 shares of common stock of Industrial Rayon.

A Step-up in Witco Chemical's European expansion program affects operations both in England and on the continent. Acquisition of minority interest in Witco Chemical Ltd., its English subsidiary, election of the managing director to the parent company's board of directors are recent developments.

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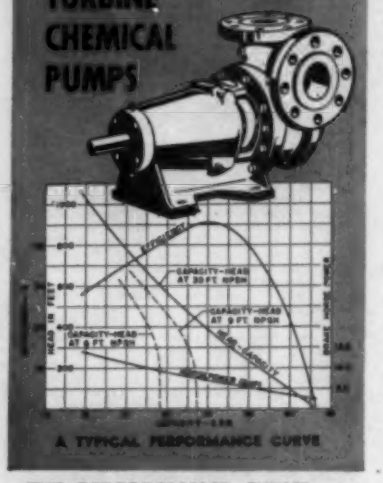

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The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 3 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive carefully consideration if received before August 15, 1960, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Baldwin, Thomas L., *Madison Heights, Va.*
Barrett, J. H., *La Marque, Texas*
Bowden, William S., *Tulsa, Okla.*
Burnham, J. G., *Wheatridge, Colo.*

Carlson, Robert H., *Lafayette, Calif.*
Christianson, Thomas K., *Marinette, Wisc.*
Clelland Wm. M., *Jenkintown, Pa.*
Clemmer, J. Bruce, *Salt Lake City, Utah*

Dansberger, Alexander H., *Tonawanda, N. Y.*
Duke, Alan R., *Pasadena, Texas*

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Feder, Raymond L., *Philadelphia, Pa.*

Gilmont, Roger, *Douglaston, N. Y.*
Gross, Irving J., *Hamden, Conn.*

Herbst, Harold John, *St. Louis, Mo.*
Johnson, Gene A., *St. Paul, Minn.*

Kendall, H. Benne, *Cleveland, Ohio*
Kendall, Jack B., *Kennewick, Wash.*
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Murray, J. E., *Texas City, Texas*

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Sheldrake, C. William, *Bethlehem, Pa.*
Sidebotham, Norman C., *Decatur, Ala.*
Stallings, U. Urban, *Casper, Wyo.*
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Stover, Albert M., *Oxford, Conn.*
Swift, W. H., *Richland, Wash.*

Vogt, E. G., *Alexandria, Va.*

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Wilmarth, A. W., *Marshall, Texas*
Wood, David H., *Bryn Mawr, Pa.*

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Ambruso, Rocco N., *Long Island City, N. Y.*
Amelio, Salvatore A., *Pittsburgh, Pa.*
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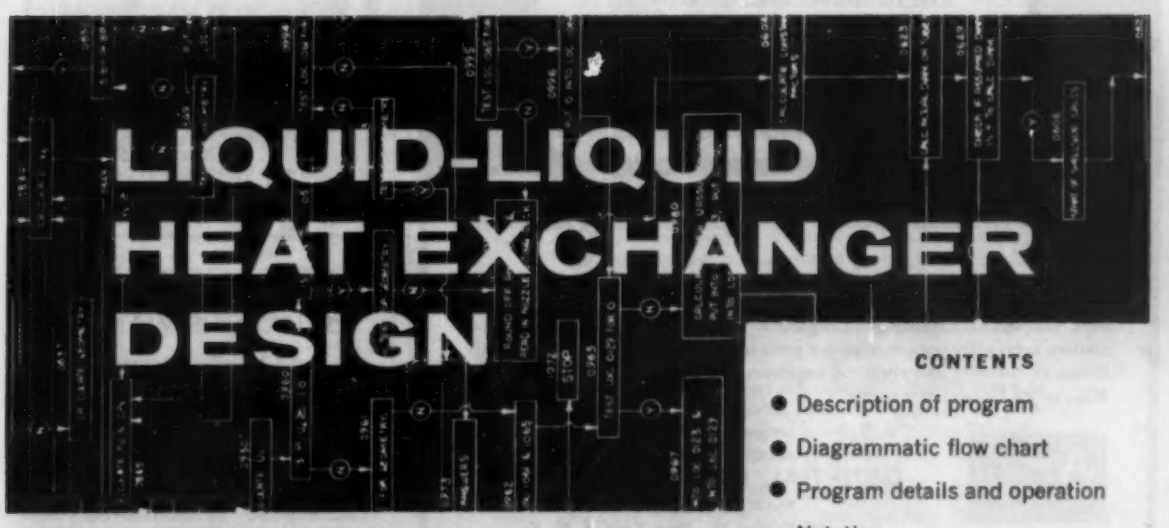

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(continued from page 163)

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Western Division

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These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Chemical, Civil, Electrical, Mechanical, Mining, Metallurgical and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 60% of the first month's salary if a non-member, or 50% if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

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CHEMICAL ENGINEER, graduate, preferably with knowledge of basic steam power plant design and experience in water chemistry, for work associated with testing of nuclear power plants. Must be U. S. citizens. Location, New England. W-9132(b).

SALES ENGINEER, chemical engineering graduate, with 8 to 10 years' background and experience in process and plant design for ammonia, acetylene, sulfuric acid, nitric acid and heavy chemicals, to secure opportunity to bid on new plants and plant expansions involving engineering design and construction. Will assist in preparation of preliminary estimates; discuss engineering and design problems with clients. Analyze data for development of new design of process as to possible adaptation and offer to new business areas. Salary, to $12,000 a year. Company pays placement fee. Location, New York, N. Y. W-9113.

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CHEMICAL ENGINEERS. (a) Chemical Engineers, graduates, with at least 2 years' experience in industry; food manufacturing experience preferrable but not necessary. Preference will be given to applicants who have some connection or living experience in Latin America. Should be willing to spend up to one year learning business. Must speak fluent Spanish or Portuguese as well as English. Salary open. (b) Chemical Engineers, Trainees, graduates, willing to work out of U. S. No previous experience in industry required. Fluent Spanish or Portuguese as well as English. Should be willing to train for as much as one year followed by one or two years' experience in a plant before any specific assignment of responsibility. Salary open. Locations: Under-developed parts of some of the South America countries. F-9086.

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CHEMICAL ENGINEERS. (a) Chemical Engineer, graduate with at least 5 years' experience in pilot plant develoment and process design. Should be strong in the understanding and use of engineering fundamentals while showing successful record of experimental and/or development work. Salary, $7500-$10,000 a year. (b) Chemical Engineer, graduate, with 3 to 8 years' experience in process and economic evaluation, with strong background in thermodynamics, heat and mass transfer and unit operations. Salary, $7,000-$10,000 a year. (c) Junior Chemical Engineer, graduate, for design and pilot plant operations. Salary, $6000-$7500 a year. Location, New Jersey Metropolitan area. W-8758.

MAINTENANCE ENGINEERS with 2 to 5 years' experience in chemical industry for assignments in maintenance and engineering departments of major petrochemical plant. Location, Illinois. W-8740(b).

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Proposal Engineer, chemical graduate, with considerable project engineering and chemical plant construction experience covering analysis, estimates, specifications and preparation of reports, quotations and contracts. Salary, $10,800-$11,400 a year. Location, New York, N. Y. W-8723(a).

SALES ENGINEER, chemical engineer or chemist, for textile and chemical sales. Must have unusually good background in sales with strong achievement record; 5 to 15 years' experience. Salary, about $10,000 a year. Location, central New Jersey. W-8721.

PROJECT ENGINEER, graduate chemical, with strong mechanical aptitude, with 3 to 8 years process development experience in high temperature insulation. Will be responsible for project from bench to pilot plant production. Salary open. Location, central New Jersey. W-8697(a).

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CHIEF ENGINEER, graduate chemical, mechanical or electrical, with Master's in instrumentation and control desirable; experience in systems engineering in instrumentation manufacturing, application engineering, sales management and supervisory background desirable. Will design and apply instrumentation systems for power and process applications; act as liason agent with companies manufacturing systems; supervise estimating and service department, etc. Salary $10,000 a year plus profit participation. Location, New York, N. Y. W-8656.

DEVELOPMENT ENGINEERS, creative chemical engineers, with 3 to 10 years' experience in continuous processing. Experience with small scale setup with emphasis on data-taking would be helpful. Experience in taking laboratory processes through pilot plant into a large scale continuous operation most desirable. Experience in fluids handling and solids handling helpful. Polymer background preferred. Should be familiar with instrumentation and adaptable to process variations. Salaries open. Location, Midwest. W-8650.

TEST ENGINEERS, degree in chemical engineering, plus up to 3 years' experience, to analyse, set up and supervise the conducting of tests for customers or for development work on any equipment and make design or process recommendations resulting therefrom. Conduct tests in the field, handle internal inquiries on test applications, maintain close cooperation with sales and applications engineering departments. Apply by letter including complete resume and salary requirements. Location, upstate New York. W-8644.

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SITUATIONS OPEN *continued on page 170*

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1—Baker Perkins Size 20, 2000 gal. double arm jacketed vacuum mixer with double naben blades
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BOX 1-7

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A.I.Ch.E. Members

(continued from page 165)

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SALES ENGINEER—B.S.Ch.E. with additional business studies. Ten years' extensive experience sale and application automatic control equipment for process industries. Desire promising sales or sales-application opportunity with medium to small company. Box 45-7.

CHEMICAL ENGINEER—B.S.Ch.E., P.E., age 32, family. Eleven years' experience in petrochemicals production supervision and process development. Strong on instrumentation and mechanical aptitude. Prefer western location. Box 47-7.

NON-MEMBERS

MECHANICAL AND CIVIL ENGINEER—M.S. in C. E. Age 39. Desire responsible position in design engineering. Fourteen years' experience, including eight years' with chemical processing industry. Present salary $10,800. Box 39-7.

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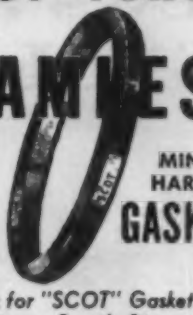

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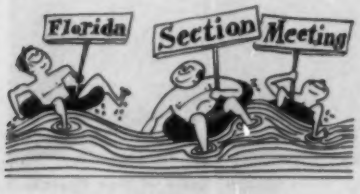
News and Notes of A.I.Ch.E.

Purely personal—This spring has been full of many pleasant events for me in my work with the A.I.Ch.E. As I traveled around speaking to the Local Sections and Student Chapters, I observed a number of interesting developments that for one reason or another I should like to pass along here. . . . One of the most unique experiences was the reception given by Ohio State graduates to Joe Koffolt at the dedication of the new Chemical Engineering Building, which Joe described as "the most beautiful building in the world." When Joe was introduced, the entire audience, including many of his former students, his "jewels," as he calls them, rose and applauded him for a long and highly "decibelic" period in tribute to him as a teacher and friend. . . . During another interesting trip this spring, I met the officers and members of the Washington, Baltimore, Savannah River, and Peninsular Florida Sections. The amount of work and good will evidenced by the chemical engineers responsible for the programs at these Sections attests to the vitality and professional attitude of the chemical engineers. The Florida group "takes over" a motel on Daytona



Beach for a two-and-a-half-day annual meeting which wives and children enjoy as much as the engineers. . . . Had a nice letter recently from R. Norris Shreve, a long-time member of A.I.Ch.E. and professor of chemical engineering at Purdue University. Norris is now director of a contract that Purdue has to aid engineering in all its phases on the Island of Formosa—the Purdue-Formosa Engineering Project—and he says that within recent years he has been back and forth across the Atlantic or Pacific some sixteen times. The most interesting part of his letter, however, is the news that the Norris and Eleanor Shreve Fund in the Purdue Research Foundation has been set up and that the first annual prize for chemical processing was made to Lyle F. Albright, Professor of Chemical Engineering at Purdue University. . . . An interesting bit of old lore was given me by A. M. Taylor, now an emeritus member, retired for many years to Spartanburg, South Carolina. On his recent visit to New York, A.M. and I got together and in reminiscing about the old days he told how when he was on the Admissions Committee each member of the committee had to buy a round of drinks for the whole committee when the number of members in the A.I.Ch.E. reached the year of his birth. A. M. remembers buying the round when the total membership reached 1876. He would have been a charter member of the Institute if the founding fathers had been able to define chemical engineering and so had included him among them when he was superintendent of one of the general chemical plants. . . . A less pleasant note about a meeting with an old friend is my visit several weeks ago with the Secretary Emeritus, Steve Tyler, at the hospital where he was confined after breaking his hip. Modern surgery being what it is, they have pinned the bone together and Steve is now getting around very nicely but would, I'm sure, like to hear from all his old friends, who can send him a note at his home address: 417 Patton Avenue, Bound Brook, New Jersey. . . . During the spring also I had a visit from Dave Boyd. I am sure that all the readers of *Chemical Engineering Progress* will remember Dave as the man who, with the help of high school students, built a computer in his cellar and recently got in the newspapers and magazines for having entertained a number of visiting Russian scientists at his "typical American home" (with a computer in the cellar). Dave told me that the computer now has an 8,000-word memory, and for readers not acquainted with the complexity of computers, I might point out that the IBM 650 has only a 2,000-word memory. Dave was one of the American representatives to a Control Conference in Moscow last month.

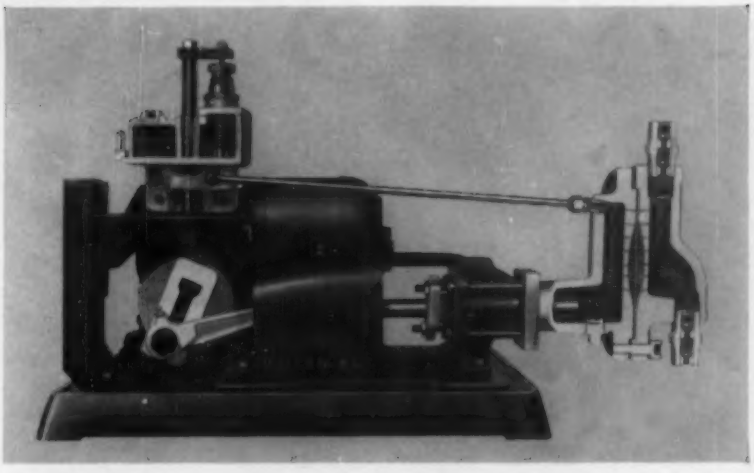
Banner membership year—This year has all the appearance of being one of the best membership years the A.I.Ch.E. has had. As of this moment we are rolling along at a higher rate than ever, thanks to the good work of the Membership Committee under Irv Leibson and his lieutenants. Those

who like to keep up with the membership drive will want to know that, despite the report in this year's Directory Supplement that there was a Northern and Southern Division of the Membership Committee, actually, as Sam West, who is Vice-Chairman of the Industrial Section, informs me, the Membership Committee is not now divided that way, but has instead an Industrial and an Academic Section.

New Local Section—Recently I had the pleasure of informing H. E. Griswold, former chairman of the club, that Council had granted a Local Section charter to the Mid-Hudson Chemical Engineers' Club. The section has been operating for well over a year as a club; its current officers are P. J. Keating, Jr., chairman; W. D. Stepanek, vice-chairman; L. E. Ruidisch, secretary; and E. T. Child, treasurer. L. C. Kemp, Jr., is the Section Liaison to Council and, the Mid-Hudson group being right in his backyard at Beacon, New York, he has a paternal interest in it.

F.J.V.A.

how to meter corrosive liquids safely and accurately



Cross-section of Milton Roy diaphragm pump shows how positive mechanical venting compensates for minor variables, eliminates air-binding.

THE problem of metering highly corrosive, toxic, or dangerous liquids can frequently be solved with a diaphragm type controlled volume pump. In this design, the plunger displaces a hydraulic fluid, which in turn moves the leakproof diaphragm to create pumping action through the ball checks.

Isolating the plunger and drive from the process fluid solves the corrosion problem, but it introduces another problem—air binding—that must be overcome to assure accurate, dependable metering. Milton Roy eliminates the air binding problem by automatically and mechanically venting the pump chamber once each stroke.

Air binding

The plunger, or hydraulic side of the diaphragm is essentially a *closed* system. An air bubble caught in this system contracts and expands with each stroke, destroying accuracy in proportion to the change in air bubble size. This "air binding" effect can reduce pumping efficiency to the point where pumping actually ceases!

This complete kit lets you convert any Milton Roy packed plunger MD pump to a diaphragm liquid end pump.

But that can't happen with a Milton Roy pump. For a brief period during each cycle, the reservoir ball check opens while the plunger reciprocates through a fraction of an inch without diaphragm motion. During the suction portion of the stroke, hydraulic fluid flows into the pump chamber to make up any losses. During the discharge portion, any excess fluid or air present is forced out of the system. This positive mechanical action not only eliminates air binding, but compensates for any minor variables which may affect pumping accuracy. Milton Roy takes the further precaution of isolating the hydraulic fluid from the drive train. There are no gears, worms, or trunnions beating air into the fluid.

Interchangeability

Any Milton Roy MD pump can be equipped with a diaphragm liquid end quickly and easily. A kit is available with all necessary parts and instructions. It's the ideal way to modernize your packed plunger pumps to keep pace with changing process requirements. Diaphragm liquid ends are available in steel, 316 SS, Milroy* SS, plastic, and special sulfuric acid construction. Diaphragms are either Teflon (standard), or 316 SS for process temperatures above 350 F. Complete pumps or conversion kits provide capacities up to 224 gallons per hour, pressures to 2,500 psi.

*Tradename of Milton Roy Co., Phila., Pa.

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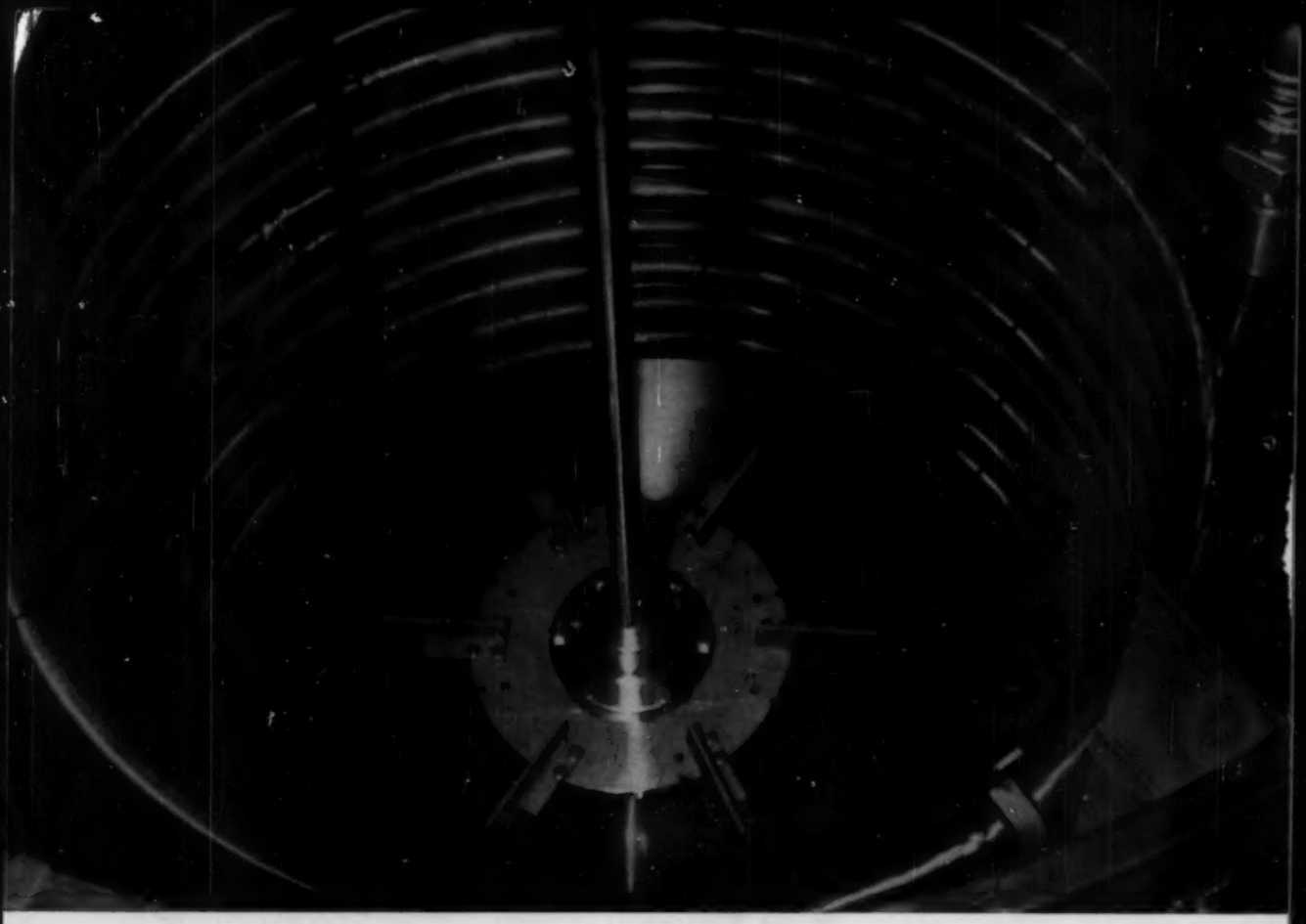


h

The best heat-transfer surface for a mixing vessel lies hidden in a jungle of variables.

An equation developed by MIXCO helps to guide investigators through this thorny thicket.

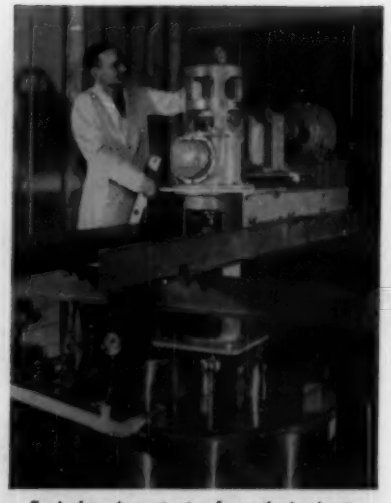
This equation correlates heating and cooling data for helical coils in a baffled mixing vessel with a flat-blade turbine. If the thermal characteristics of a fluid are known, the heat transfer coefficient can be easily calculated.

The correlation takes into account variable impeller speed, size, power input, baffle position, tube diameter, and tube spacing. It's applicable to any tank size, to fluid viscosities from 0.4 to 20,000 centipoises, and to a Reynolds-number range of 10 to 1,500,000.

Among other useful indications, this heat-transfer correlation shows that you get best values of *h* with impeller flow as large as practicable, and with tube diameter small as practicable. It helps to settle the problem of where to locate baffles. It throws new light on the relative efficiencies of helical coils and vertical tubes for heating or cooling.

To pin down accurate values of *h* in this investigation, some elaborate methods were employed. Thermocouples embedded in the tube wall made possible direct measurement of temperatures across the fluid film. Continuous recording of temperatures in more than 20 carefully selected positions in the tank gave a valid calculation of average system temperatures. Duplicate runs, under steady-state and unsteady-state conditions, produced excellent agreement in results.

This is just one example of the lengths to which MIXCO research is prepared to go to help you process fluids efficiently. If you'd like a reprint of a four-page article describing this heat-transfer correlation, you can get it by writing to our Research Department.



Typical equipment setup for gathering heating and cooling data in coil-equipped vessel.

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